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WEEKLY November 14 - 20, 2015

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THE ALIEN WITHIN

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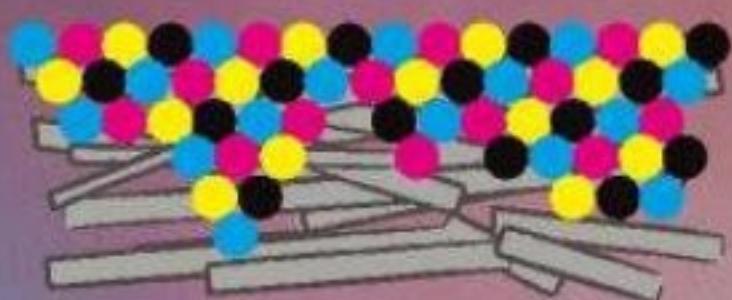
LIGHTS, CAMERA, AXION Bit-part particle lands surprise lead role

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News

8

Dark matter of life revealed

A whole new domain of life might be living inside our guts



MARTIN DEGERLI/MICRONAUT

On the cover

30

Your billion year history

Fantastic journeys of the stuff that makes you

Cover image
 Sam Chivers

- 11 Final countdown**
Body clock ticks away
- 12 Hammer horror**
Deep dives with the world's strangest sharks
- 8 The alien within**
Mystery life forms in your gut
- 22 Secrets and spies**
What the snoopers' charter means
- 36 Lights, camera, axion**
Bit-part particle shines

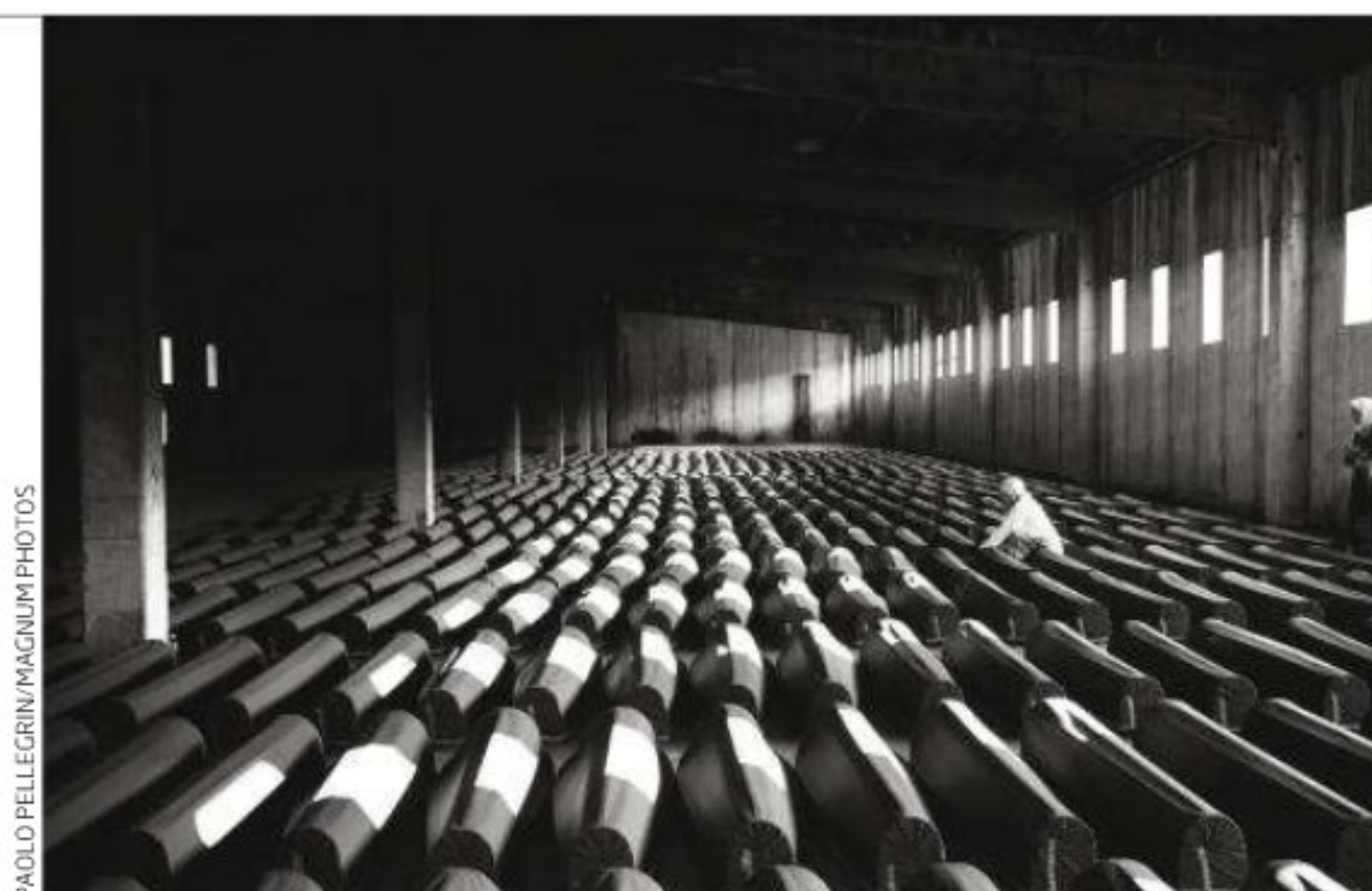


Features

40

Roots of evil

The brain changes that underlie brutality



PAOLO PELLEGRIN/MAGNUM PHOTOS

Coming next week...

Gut thinking

The surprising ways food controls your mind

Beyond Pluto

New Horizons begins its final mission

Leaders

- 5** US must lift budget caps on science for good

News

- 6 UPFRONT**
Obama kills Keystone pipeline. Mexico declares marijuana use a human right. Pope changed minds on climate. Exxon's cover-up probe
- 8 THIS WEEK**
The sun stole some of Mars's atmosphere. What now for gene editing after leukaemia success. Cellular clock counts down your life. Quantum confusion still reigns
- 12 FIELD NOTES**
Free diving with elusive hammerhead sharks
- 17 IN BRIEF**
Bat-riding pseudoscorpions. Mass extinctions blamed on mineral deficiency

Technology

- 20** Pitfalls of the UK's "snoopers' charter". 3D print spare parts. Who really writes the laws?

Aperture

- 26** Cold war relics abandoned in snowy wastes

Opinion

- 28 Warming up for Paris** David Victor says forget the 2 °C cap and look for other successes at crunch climate talks
- 28 Keep it cool** The cap is still achievable, says Bob Ward
- 29 One minute with... Yuri Milner** My awards will transform scientists into rockstars

Features

- 30 Your billion year history** (see above left)
- 36 Lights, camera, axion** Bit-part particle lands a surprise lead role
- 40 Roots of evil** (see left)

CultureLab

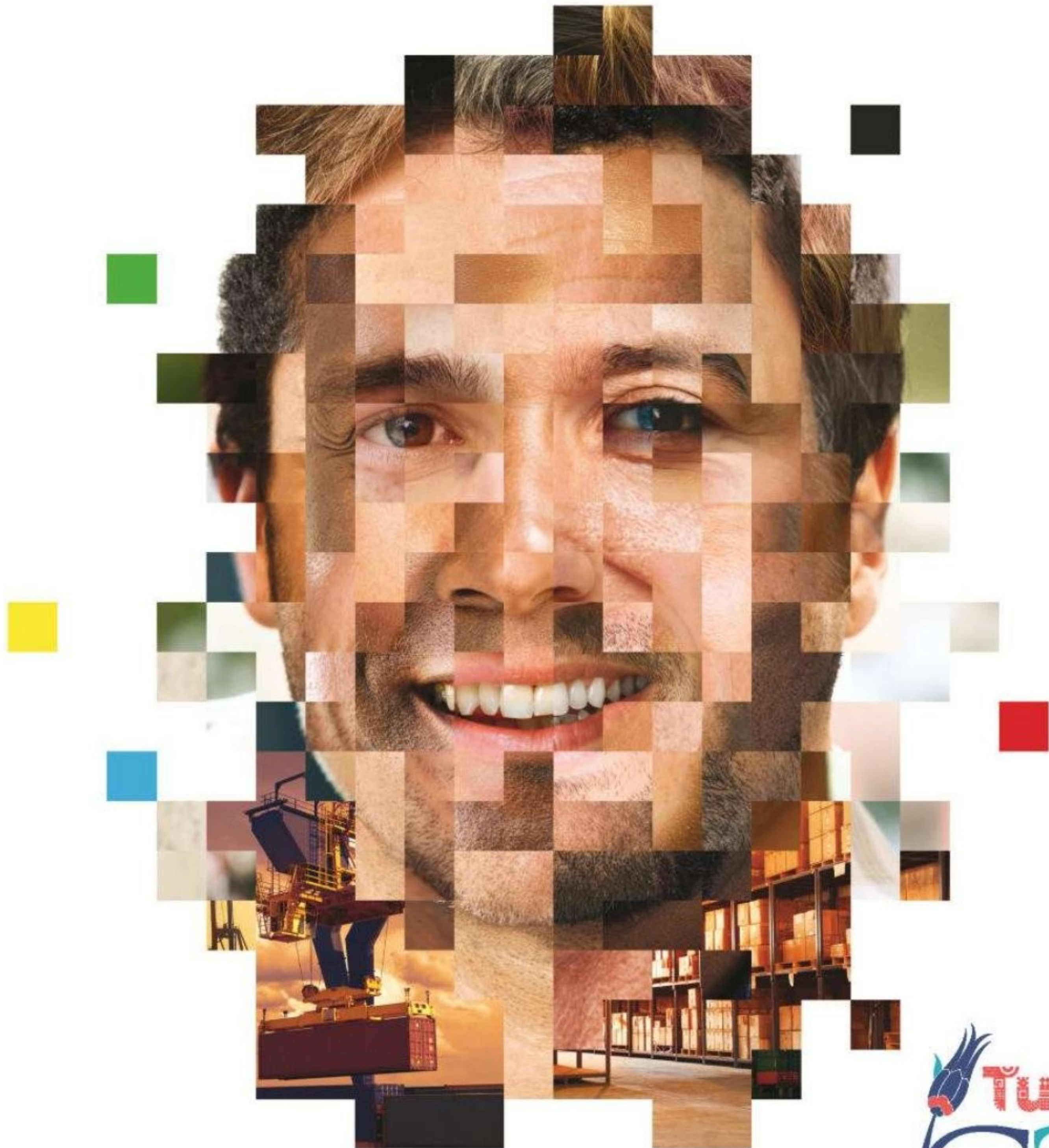
- 44 Secrets and lies** Why are we still torturing people when we know it just doesn't work?
- 45 Green lessons** The destructive history of two countries sheds light on our eco attitudes

Regulars

- 52 LETTERS** Energy cost of shared showers
- 56 FEEDBACK** Bonkers drugs bill
- 57 THE LAST WORD** Oil slick thinking

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MARNIE BURKHART/PLAINPICTURE

Unshackle science

For the US to prosper, research budget caps must be scrapped

SCIENCE and technology are the wellspring of innovation, new jobs and economic progress, but the US is underinvesting in them. The bipartisan budget deal reached in late October offers some much-needed relief for federal science agencies, but it remains a temporary fix for programs hit by the spending caps known as “sequestration”, which took effect in 2013.

The deal eases the caps, increasing total discretionary spending by 5.2 per cent for the 2016 fiscal year. Research and development budgets tend to track such increases. That is good news for the National Institutes of Health, for example, for which Senate appropriators had already sought a \$2 billion rise – the largest yearly boost in a decade. It could also improve prospects for the Obama administration’s desire to boost funding by 5 per cent for the National Science Foundation and the Department of Energy’s Office of Science.

Now the bad news. The deal is set to expire after two years. That will make planning difficult for laboratory directors, leaving the future of the scientific enterprise uncertain. If policymakers leave the sequestration caps in place when the budget deal expires, and make no exception for science



COURTESY JOHN RICE

PROFILE

Rush Holt is chief executive officer of the American Association for the Advancement of Science (AAAS) and executive publisher of *Science*

and technology, the US will invest tens of billions of dollars less on federal R&D over the next decade.

That would continue a worrying trend. Federal R&D spending represents less than 0.8 per cent of GDP – down from 1.25 per cent in 1977. As a proportion of the federal budget, R&D investment has shrunk from 10 per cent in 1967 to less than 4 per cent now. The private sector has not filled the gap; we dropped to tenth place in the world in terms of research intensity – a measure of combined public and private spend on R&D as a share of GDP.

Such underinvestment not only

slows scientific advancement, it also threatens the nation’s ability to address pressing global problems such as food, water and energy shortages, climate change and disease. Looming challenges, such as the predicted doubling every 20 years of dementia cases globally, may go unmet.

Sequestration caps should be dropped by Congress once and for all. Our future depends on a bipartisan consensus about the value of consistent, dependable federal R&D budgets. Without this, we risk missing the next big thing. Magnetic resonance imaging, lithium-ion batteries, liquid crystal displays, signal compression and magnetic storage devices all resulted from federally funded research. The algorithm that led to the Google search engine was developed by Larry Page and Sergey Brin while they were graduate students working under a National Science Foundation grant.

The US must reposition itself as a world leader in science. Stronger investments now will bolster innovation and global scientific advances for years to come. ■

We are publishing simultaneous Leader articles on science funding in Australia and the UK: see newscientist.com/opinion



Americans are listening

Pope's climate call heard

WHEN the leader of the world's 1.2 billion Catholics called for action on climate change in June, observers wondered whether this would move the needle in the public debate.

A survey of people in the US now suggests that it has. Pollsters interviewed the same nationally representative sample of more than 900 respondents before the release of the pope's encyclical, a major document setting out Catholic doctrine, in June and after his trip to the US in late September.

Some 17 per cent of all respondents and 35 per cent of Catholic respondents said they were influenced by Pope Francis's message that climate change is a crucial moral issue. The percentage of Catholics who said they were "very worried"

about global warming more than doubled compared with spring. And the number who denied the scientific consensus that human-caused climate change is happening declined by 10 percentage points among Catholics and 6 points among the US population in general.

"We were expecting to find fairly small changes. The magnitude of the shift was surprising to me," says Edward Maibach of George Mason University in Fairfax, Virginia. "In many of the specifics of the way people view climate change – for instance, seeing it as a moral issue and understanding that climate change is going to hurt people in developing countries and the world's poor the most – we saw really large shifts."

Pluto ice volcanoes

THEY sure look like ice volcanoes. An avalanche of data released from NASA's New Horizons probe, which flew past Pluto on 14 July, show the dwarf planet has a pair of potentially volcanic

pits in their centres. They most closely resemble shield volcanoes like those on Hawaii, which are built up by layers of magma erupting over time rather than by the action of plate tectonics.

On Pluto, a slurry of nitrogen and water ice melted by subsurface heat stands in for lava, the team suggests, freezing solid once it is exposed at the surface.

"Whatever there are, they're definitely weird, and volcanoes are probably the least weird explanation at the moment," says New Horizons team member Oliver White.

"They're definitely weird, and volcanoes are probably the least weird explanation at the moment"

mountains near its south pole.

Volcanoes are common on the solar system's rocky inner planets, but they weren't expected so far out. "Pluto and its system of moons have really outsmarted us," team leader Alan Stern told a meeting of the American Astronomical Society's Division of Planetary Sciences in National Harbor, Maryland, on 9 November. "It's sort of a graduate course in planetary science."

The informally named Piccard Mons (5.5 kilometres tall) and Wright Mons (3.2 kilometres tall) both have the same shape as volcanoes we see on Earth: roughly circular mountains with

Exxon inquiry

TEXAS-based oil giant ExxonMobil is facing an investigation into whether it has been suppressing research findings on climate change as far back as the 1970s.

On 4 November, New York State Attorney General Eric Schneiderman issued a subpoena for documents, including financial records and emails, from the multinational relating to climate change research and advocacy.

"What's shaping up is like the situation with the tobacco companies," says Bob Ward at

the London School of Economics. "For many years, they knew the truth about the harm done by cigarettes. The question now is whether ExxonMobil was doing the same with its products."

The inquiry aims to find out whether the oil company was aware of the dangers of human-made climate change but chose to keep quiet and to promote denial groups challenging the scientific consensus that greenhouse gas emissions are warming the planet.

ExxonMobil denies the allegations.



A win for campaigners

Keystone killed off

NOW that's a death blow. US President Barack Obama is being hailed as the first leader to cancel a major infrastructure project because of its impact on climate change, following campaigns by environmentalist groups.

The Keystone XL pipeline would have transported the dirtiest and most expensive type of petroleum from tar sands in Alberta, Canada, to US refineries in the Gulf of Mexico. But Obama focused on

the lack of benefit the pipeline would have for the US, and a report to Congress on the decision didn't mention climate change.

A domestic oil boom means the US was relying less on oil imports, and the administration says other pipeline projects will allow it to get its own oil down to the refineries on the Gulf of Mexico: it doesn't need Keystone.

The trick now for activists is to stop more oil infrastructure. "We're looking to build on this victory," says May Boeve, executive director of activist group 350. "It's wrong to build any new fossil-fuel infrastructure, period."

Need for weed

IS SMOKING weed a human right? Days after voters in the US state of Ohio rejected a proposal to legalise cannabis for recreational use, Mexico has ruled that smoking pot is a fundamental human right.

The Mexican Supreme Court ruled by 4 to 1 that banning the consumption and cultivation of cannabis for personal use violates the human right to free development of one's personality.

The ruling only applies to the four individuals who brought the case to court, but widespread legalisation may follow. Several other countries have moved towards more lenient laws on cannabis use, but none has done so solely on the basis of human rights. Most, like Ireland, which in early November moved towards legalising supervised heroin use and possible decriminalisation of other drugs, have cited health and economic grounds.

Four US states have legalised personal use of cannabis and Canada is expected to follow suit. Bills to legalise cannabis for medical use are under debate in Brazil, Chile, Colombia and Costa Rica. "We're seeing a new rationality in relation to drug laws," says David Nutt of Imperial College London, who is a former UK government adviser.

World reaches 1°C

IT'S getting hot in here. Global average levels of carbon dioxide in the atmosphere temporarily broke the 400 parts per million level earlier this year for the first time, the World Meteorological Organization has announced.

Meanwhile, the UK Met Office confirmed what *New Scientist* reported first in July – that the world has now warmed by 1°C relative to pre-industrial times.

Climate models show that if CO₂ levels stopped rising now, the world would still warm by a further 0.6°C. This means that

even if global emissions were cut by 60 per cent now, which is what it would take to stabilise CO₂ levels, we would still hit 1.6°C of warming.

If emissions stopped altogether, CO₂ levels would soon fall. "That would lead to a smaller eventual temperature rise," says climate scientist Gavin Schmidt at NASA.

Unfortunately, even if countries stick to what they are proposing to do as part of the global climate treaty now being negotiated, emissions and CO₂ levels will continue to climb well past 2030. It therefore appears unlikely that warming can be limited to less than 2°C, considered to be safe.

Russia duped world on doping

HOW did they get away with it? The World Anti-Doping Agency (WADA) has uncovered a widespread and long-running "state-sponsored doping programme" in Russia.

In a report published on Monday, a commission set up by WADA accused the Russian Ministry of Sport of issuing direct orders to "manipulate particular samples", and describes "direct intimidation and interference by the Russian state" in the work of a WADA-accredited testing laboratory in Moscow. On 10 November, WADA suspended the lab.

So how did such corruption go unnoticed? WADA lacks the resources to work as a police force, and relies on national anti-doping organisations to oversee and carry out tests,

says Chris Cooper, a sports scientist at the University of Essex, UK.

The report found evidence of a "deeply-rooted culture of cheating" in Russia. Athletes used EPO and blood transfusions to boost the oxygen-carrying capacity of their blood, and steroids to build muscle. Doctors, coaches and lab staff covered up failed routine tests and ensured that by the time athletes came to compete, banned substances were no longer in their systems.

"If the national organisation isn't actively trying to catch crooks, then there's a problem," says Cooper. "It's not a science issue; it's a governance issue." The report recommends Russia be suspended from athletics competitions.



Country-wide corruption

60 SECONDS

Final frontier passed

What a breakthrough. For the first time, scientists have temporarily disrupted the blood-brain barrier – the protective layer around the brain – to deliver chemotherapy to a brain tumour. The team used sound waves to make bubbles in the blood vibrate, which allowed the drug to pass into the brain. The method could treat many brain diseases.

Sahara's secret river

A hidden riverbed has been spotted under the sand of the vast Sahara desert using radar satellite imagery. The 520-kilometre-long river rose in the Atlas mountains of Algeria and met the Atlantic Ocean in what is now Mauritania as recently as 5000 years ago (*Nature Communications*, DOI: 10.1038/ncomms9751).

Not just a fish finger

Here's a mouthful. Fish have evolved body shapes that are harder for predators to get their jaws around. According to a survey of body shapes in 347 fish families, those with vertical spines tend to have deeper bodies, and those with horizontal spines tend to have wider bodies (*Proceedings of the Royal Society B*, DOI: 10.1098/rspb.2015.1428).

The show mustn't go on

The curtain is set to fall on theatrical antics by captive orcas at SeaWorld in San Diego, California. From 2017, the shows will be replaced with displays focused on the whales' natural environment, although the current show will continue at SeaWorld's parks in Orlando, Florida, and San Antonio, Texas.

ISS delay

NASA has announced yet another delay in its awarding of contracts to ferry cargo to and from the International Space Station. The agency had intended to announce which companies it will partner with on 5 November but pushed the date back to 30 January. It has told Boeing that it is no longer in the running.

Meet the dark matter of life

We might have found a new form of life – and it's in our gut. Colin Barras reports

INSIDE each one of us lies a mystery. An analysis of genes from the human gut has found DNA so unusual it could belong to microbes unlike anything that science has encountered before.

Life as we know it is split into three major groups or domains. Plants, animals and fungi are all classed as eukaryotes, whose defining feature is their nucleus. Less complex cells fall into two different divisions – bacteria and archaea (see diagram, below).

But some biologists suspect new forms of life are still to be discovered – the equivalent of dark matter – not least because more than 99 per cent of microbes can't actually be grown in the lab.

Until about 25 years ago, we had virtually no way of studying them. Since then, genomic tools have enabled us to sequence microbial DNA and get an idea of the range of different species.

Even with these techniques it is hard to identify completely new types of life. One problem is drawing the evolutionary dividing line between different groups of microbes. Because they can swap genes, the divisions between them become blurred, and difficult to detect. And when a DNA analysis does identify gene sequences unlike any others, researchers don't know how to interpret them – precisely because they are so unusual.

Philippe Lopez and Eric Bapteste at the Pierre and Marie Curie University in Paris have come up with a solution. Working with Sebastien Halary at the University of Montreal, Canada,

they have developed a new method for identifying particularly unusual genes.

They do this by focusing on 86 families of gene that, for some reason, are rarely swapped between different microbes. They reasoned that if they could find genes from these 86 families that don't obviously belong to bacteria, archaea or eukaryotes, this might hint at gaps in our three domains of life.

In their quest, the team has turned to our guts, because the human gut microbiome is the best studied of all microbial communities, and hosts a diverse range of species.

They analysed microbiome samples, recovering about 230,000 DNA sequences that are



MARTIN OEGGERLI/MICRONAUT

related to known sequences in those 86 gene families. They then used these sequences as the starting point for a second analysis – a little like digging deeper into your ancestry by using your parents' DNA rather than your own to guide the search. This revealed an

additional 80,000 stretches of microbial DNA that belonged in the 86 gene families. But the sequence of bases was highly unusual in about one-third of the DNA – it shared just 60 per cent or less of its identity with any known gene sequences. That degree of difference is what you might expect to separate different domains of life, such as bacteria and archaea.

One explanation is that genes are more variable in known organisms than we thought, says Lopez. But there is an alternative. "It's as if they belonged to

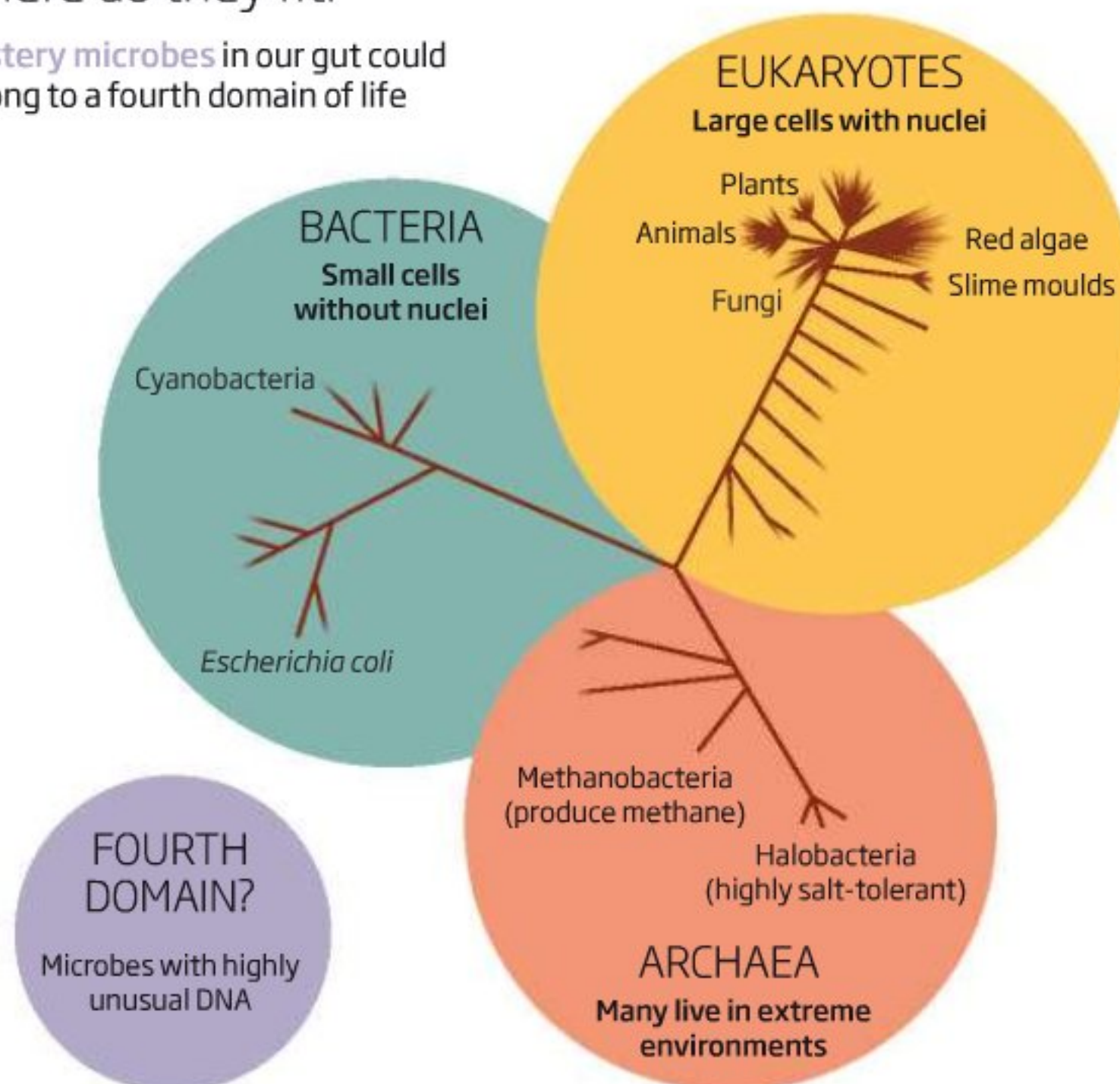
"It's as if they belonged to unknown lineages of microbes that diverged very early in life's history"

unknown lineages of microbes that diverged very early in the history of life," he says. That might mean they belong to an as-yet-unidentified fourth domain (*Biology Direct*, doi.org/82c).

Bapteste stresses that only more research will allow us to be confident that the human gut really does play host to life forms

Where do they fit?

Mystery microbes in our gut could belong to a fourth domain of life



In this section

- What now for gene editing after leukaemia success, [page 10](#)
- Free diving with elusive hammerhead sharks, [page 12](#)
- Pitfalls of the UK's "snoopers' charter", [page 20](#)



Teeming with alien life?

that defy classification, especially as we know nothing about the microbes that carry the strange genes. "Let's wait to see how unusual the organisms are," he says. In particular, it would help to know about their size and their internal structure, including the ribosomes they use to make proteins. The cell's metabolic processes might be unusual too, says Baptiste.

But there's no reason why we couldn't find a new domain of life inside us. "Scientists have found a huge diversity of microbes in the human gut, so I would not expect it to be necessarily hostile to different life forms," says Baptiste. Last year, Dusko Ehrlich at the French National Institute for Agricultural Research in Jouy-en-Josas was part of a consortium that updated the catalogue of genes in the gut microbiome, expanding our estimate from 3.3 million to 9.9 million. "The gut microbiome is not such a well-known playground," he says.

But the big question remains: could it really play host to microbes from a fourth domain? "The evidence is suggestive and

indeed tantalising, but would need to be confirmed," says Ehrlich.

"I am not entirely sure what the results really mean," says James McNerney at the University of Manchester, UK, whose research looks at the origins of the three known domains of life. He suspects that the unusual genes will turn out to belong to fairly ordinary microbes – particularly since researchers are beginning to appreciate that gene diversity might be more extreme than once thought. That would still be an exciting find, he says. "It might hint at new metabolic processes at work in our guts."

McNerney also points out that the proposed fourth domain of life still eludes us even after 25 years of sampling DNA from the environment. But Lopez and Baptiste argue this is because recognising completely new microbes is, by definition, a challenge.

All can agree that the true significance of the new findings won't become clear until they have actual cells containing the unusual genes – the next task on the agenda. "The good news is we now know something about them that could help us to fish them out," says Baptiste. Like most microbes, they probably can't be grown in the lab, but Baptiste says developments in a technology called single cell genomics should soon offer a way to sequence the genome of individual microbes, even if they can't be cultured.

If the results reveal microbes as unconventional as their genes appear to be, biology might change – just as it did 30 years ago when researchers first realised that the archaea formed a distinct third domain of life. "The discovery of archaea revolutionised our fundamental knowledge in biology," says Baptiste. For now, he says, we should remain cautious. "These deep lineages, if they exist, still need to be captured." ■

Solar burps may be behind loss of Martian water

THE Martian weather report is in. Information beamed back by NASA's MAVEN spacecraft, which has been studying Mars's atmosphere from orbit since September 2014, offers a new view of the Red Planet's history and could help pave the way for crewed missions.

One of Mars's long-standing mysteries is what happened to its water. Geological evidence found by NASA's Curiosity rover suggests the planet was once wet enough to host lakes and rivers, but barring a few salty streaks we don't see much sign of these today.

"We're trying to understand what changes in the climate have occurred and what drove them in order to go from that warm wet planet to today's cold, dry, more desert-like environment," says Bruce Jakosky of the University of Colorado, Boulder, who heads the MAVEN mission.

To that end, MAVEN is studying how water and other molecules could have escaped through the planet's atmosphere and out into space. In March this year, it watched as the sun burped out a coronal mass ejection (CME), a mix of gas particles and magnetic field lines. When this mass slammed into Mars, it generated a strong electric field in the upper atmosphere, giving a large number of oxygen and carbon dioxide ions sufficient energy to escape into space (*Science*, [doi.org/83k](#)).

This small-scale stripping of Mars's atmosphere could be an echo of the past. It's thought that the sun was once more active, with a greater frequency and intensity of CMEs. That would have stripped more gas out of the atmosphere, leaving Mars barren.

MAVEN has also performed a number of "deep dips" into the atmosphere, gathering data that could help astronauts land on the surface by using the atmosphere to safely slow down (*Geophysical Research Letters*, [doi.org/85z](#)).

Jakosky says MAVEN could also determine whether Mars's ionosphere

"We're trying to understand why Mars went from a warm, wet planet to a cold, dry, desert-like one"

is strong enough to bounce radio waves off, letting astronauts converse over longer distances on the surface. In general, he thinks MAVEN is laying down a science baseline that future missions will explore further.

He points to the opening of the recent film *The Martian*, in which astronaut Mark Watney and his crew are gathering rock samples. "What they're doing is looking to answer the questions that we're helping to pose right now," he says. "I think Mark Watney and his fellow astronauts would have been very familiar with the MAVEN mission." Jacob Aron ■



Watch out for the sun

THIS WEEK



SHARON LEES/GOSH

Layla is recovering from leukaemia

Layla's gene-editing legacy

Michael Le Page

WHAT comes next? Last week, it was announced that a 1-year-old girl called Layla has been saved from leukaemia by an experimental gene therapy. It was used as a last resort after all other treatments had failed.

It's too early to know whether Layla is free of cancer, or if the technique that saved her will work for others. But it is clear that gene editing is set to make an existing method of tackling cancer – genetically engineering immune cells to kill cancer cells – even more powerful and widely available.

"There are lots of genetic tricks we can exploit to make the cells more specific and more potent," says Adrian Thrasher, who heads the gene therapy programme at Great Ormond Street Hospital in London, where Layla was treated.

Our immune systems play a

vital role in suppressing cancers. There are immune cells called T-cells, for instance, that travel around the body seeking and destroying abnormal-looking cells that may be infected or turning cancerous. They detect these cells with the help of protein receptors on their surface.

It is usually only when cancers manage to evade these hunters that they become dangerous. And cancers have some clever tricks to do this. For example, T-cells have a receptor on their surface called PD-1, which acts as an off switch. It is used to stop cells becoming overactive and running amok. Many cancers evolve ways of flicking the PD-1 switch and deactivating any T-cells that try to attack them.

Many of the most promising new cancer treatments involve boosting the immune response. For instance, a new generation of

drugs – called PD1 inhibitors – that stop cancers turning off T-cells are producing good results when combined with other therapies.

Another encouraging approach is to genetically engineer T-cells to target cancers. Cancer cells often have proteins on their surface seldom found on healthy cells. T-cells can be programmed

"There are lots of genetic tricks we can exploit to make immune cells more specific and potent"

to recognise these by giving them genes for tailor-made receptors called chimeric antigen receptors (CARs). Biologists first began work on CARs in the 1980s, but it is only in the past few years that human trials have begun – and some results have been dramatic.

In one trial involving 53 children with acute lymphoblastic

leukaemia – the disease that Layla had – for whom conventional therapies had not worked, 29 are still in remission months or years after treatment. There are now 77 trials of CAR T-cells around the world, for treating several different cancers of the blood.

It is not a miracle cure, of course. CAR T-cells can cause adverse reactions by overstimulating the immune system, particularly in adults. Cancer cells can evolve to dodge the T-cells, by no longer expressing the target protein.

Another issue is that a patient's T-cells have to be removed, genetically modified and replaced. If T-cells from a donor are used, the donor cells will view all of the patients' cells as foreign and attack them. This makes the treatment expensive – and in some cases, like Layla's, doctors can't get enough T-cells to modify. She was too small and sick.

This is where gene editing comes in. With conventional gene therapy, it is only possible to add genes. With gene editing, though, genes can also be disabled – opening up new, cheaper, possibilities.

The Great Ormond Street team was able to use donor T-cells to treat Layla because in addition to the CAR gene, they used gene editing to disable the gene for the protein that recognises other cells as foreign, thereby preventing the donor cells from attacking Layla's healthy cells.

The result, at least in this one case, was spectacular. "It's incredibly encouraging," says Waseem Qasim of University College London, who helped to develop the treatment. "There are a whole bunch of other disorders we can now create fixes for."

The aim of this work is to develop "off the shelf" CAR T-cell therapies, so that hundreds of people can be treated with the same batch of cells.

Even so, in many cases there is yet another hurdle to overcome, because the patient's own

immune system will see the donor T-cells as foreign and kill them. This was not an issue with Layla, because her immune system had been wiped out by the treatments she was given.

So Carl June of the University of Pennsylvania in Philadelphia has gone further to allow the therapy to work in other people. His team has used CRISPR gene editing to also disable the gene for the HLA proteins that mark a donor T-cell as foreign, reducing the chances of the recipient's immune system attacking the donor cells.

Permanently on

June's team has also disabled the gene that makes the PD1 receptor in the T-cells. In other words, the group removed the off switch, so the cancers can't use it to deactivate the CAR T-cells. The cells have been successfully tested in mice with a form of leukaemia, the team will tell a meeting of the American Society of Hematology in December.

June's work was funded by healthcare giant Novartis, one of several companies developing the technology. Novartis hopes that standard CAR T-cell treatments will be approved in the US in 2017. But it may be many more years before off-the-shelf T-cells created with gene editing get approval, says Usman Azam, head of cell and gene therapies at Novartis.

One question is safety: the molecular scissors used to edit genes sometimes make cuts in the wrong place. These "off-target" effects could in theory have rare adverse effects such as turning cells cancerous.

The biggest question is whether this approach will also work against solid tumours. These are harder to attack than blood cancers like leukaemia, not least because they contain many cell types. So far it does not appear that CAR T-cells alone will get rid of solid tumours. But they may work well as part of a combination of therapies, says Azam. ■

'Death clock' in cells counts down to cancer

TICK-tock, tick-tock. How fast we age and whether we get cancer may be predetermined by two "clocks" discovered in almost every cell in the human body.

Each tick of these clocks is a DNA mutation, and these build up at a constant rate throughout your life. The discovery will give us a deeper understanding of the causes of cancer, and an insight into healthy ageing. Not only that, but if you could slow the rate at which these clocks tick, it might be possible to alter the rate at which cancer spreads - and even the rate at which we age.

Every cell in the body contains DNA, which acquires gene mutations over time. These mutations can sometimes occur in bursts - for example, as a result of smoking or overexposure to the sun. Or they can build up slowly over decades.

Some mutations seem to accumulate at a constant rate year by year, causing DNA damage that can lead to cancer. Now, Michael Stratton at the Wellcome Trust Sanger Institute in Cambridge, UK, and his colleagues have identified two such mutational clocks in almost every cell in the body.

They have also figured out how fast these clocks tick in different tissues.

The team started by studying the DNA sequences of more than 10,000 individual cancers, encompassing 36 different types. An algorithm allowed them to search the cancer genomes for complex patterns of mutations called signatures.

They discovered more than 30 different signatures. They then identified which of these occur in a clock-like manner, with mutations appearing at a steady rate. Two signatures - numbers one and five -

"How fast the clocks tick may indicate how fast a cancer spreads - or even predict it in the first place"

fitted the bill. Stratton showed that the clock began in healthy tissue before it became cancerous. "The cancer tissues are the cracked and dirty lens that allow us to look back in time to look at what's been happening in normal cells," he says.

The team believes signature one is a "mitotic clock", a mutation that occurs as a result of cell division. "The

rate of mutations correlates with the rate of cell turnover in tissues. So in future we'll be able to use the number of mutations from this signature to know how many times a cell has divided, giving us a deep insight into the biology of human tissues."

Far less is known about signature five. Preliminary hypotheses suggest it may be linked to DNA repair. Over time, DNA gets damaged and has to be patched up. Signature five might be the outcome of that.

For both signatures, the number of mutations correlated with the age of the person that the sample came from - the older they were, the more they had accumulated. This helped the team figure out how fast the clocks were ticking in each tissue. For instance, signature one ticked quickest in stomach and colon cells, which resulted in about 23 mutations per cell a year, and slowest in breast and ovarian cells, which had three to four mutations a year (*Nature Genetics*, DOI: 10.1038/ng.3441).

Because the clocks continue to tick once a healthy cell becomes cancerous, knowing how fast they do so could help indicate how fast a cancer may metastasise and spread around the body, or become resistant to a drug. This would allow doctors to plan the best course of action for a patient. They might even be used to predict cancer before it starts.

"We accumulate mutations over a lifetime and in some people the correct combination leads to a cancer emerging," says Stratton. If mutation rates differ between individuals, "those rates could be read out to predict the time they might take to become cancerous".

In theory, if you could alter the rate at which the mutations are occurring, you might be able to change the rate at which cancer occurs. "I'm not saying this as a possibility but this discovery inevitably leads you onto that kind of thinking," says Stratton.

The discovery could also offer an insight into the way we age. "These two processes could contribute to ageing and their presence at a constant rate could predetermine the rate of ageing," says Stratton.

Helen Thomson ■



IMAGEBROKER/ALAMY

Time and mutations wait for no one

FIELD NOTES Mikomoto Island, Japan

Free-diving to tag elusive sharks

David Jacoby

I AM 30 metres underwater, my view of the world above blocked by around 60 scalloped hammerhead sharks cruising overhead. It's an iconic silhouette, one I had only seen on television until now.

I'm awestruck, but this school of sharks is exactly why I'm here – to work out why such large groups of this beautiful predator gather near the island of Mikomoto for just two months every year. This question has puzzled researchers for decades. With the help of a free-diver, we hope to solve it.

Here in the turbulent waters of the Pacific Ocean 10 kilometres offshore from the town of Minato, in Japan's Shizuoka prefecture, groups of up to several hundred hammerheads gather every summer, but we don't know why.

Back in the 1980s, marine biologist Pete Klimley suggested that similar schools in the Gulf of California were a social refuge – a space for females in particular to get some downtime, saving energy by swimming together, and possibly avoiding male harassment, which is common in sharks.

But this hypothesis remains untested, in part because the

animals are so unpredictable and elusive. That's where professional free-diver Mark Healey comes in. A remarkable surfer and athlete, we have enlisted his help to assist with electronically tagging as many hammerheads as possible.

Scalloped hammerhead sharks are naturally wary and very

"The key is in the approach – they need to feel as if you are swimming with them, not after them"

difficult to approach. They are also traumatised by being captured – the stress is sometimes enough to kill them. We are hoping that free-divers, who can swim underwater for up to 8 minutes without needing any breathing equipment, will be able to get close to these sharks without disturbing them.

"The key is in the approach – they need to feel as if you are swimming with them, not after them," Healey tells me after a "short" dive of roughly 4 minutes. He grew up swimming off the coasts of Hawaii, which might explain his calmness in the water with so many sharks.

Our project involves specialists from the UK, US and Japan, and we are working with the local



Dive like a shark

fisheries agency and a dive ecotourism company, Mikomoto Hammers, to tag sharks off the rocky island of Mikomoto.

In the end, we spent a week battling the swell caused by the approaching Typhoon Goni to find and tag hammerheads. Guided by our Japanese colleagues, we managed to tag 10 sharks just behind their dorsal fins, eight with acoustic tags and two with satellite tags. We did this largely with modified spearguns wielded by free-divers – the tagging method believed to be least stressful for the sharks.

The satellite tags will send us location data whenever a shark surfaces, while the acoustic tags will trigger a time-date stamp whenever it passes within 250 metres of six acoustic receivers we planted around the island at depths of up to 23 metres.

This is an excellent start. For two years I have been developing methods for inferring social interactions between individual sharks based on location data

from tags. Once we have tagged around 40 sharks – we are planning a second trip next year to tag more – I'm going to work with Austin Gallagher at the University of Miami in Florida, Yannis Papastamatiou at the University of St Andrews, UK, and Yuuki Watanabe at the National Institute of Polar Research, Japan, to work out the social network structure of this shark school.

This should help us understand how and why these schools form, and allow us to test Klimley's hypothesis. It may also prove vital for the survival of this endangered species. Coming together in such large groups makes the sharks more vulnerable to fishing, and these waters are dangerously close to some of East Asia's hubs for global shark fin trade.

As we climb aboard for the last time, Typhoon Goni approaching, I can't wait to start retrieving the acoustic detection data. ■

David Jacoby is an ecologist at the Zoological Society of London

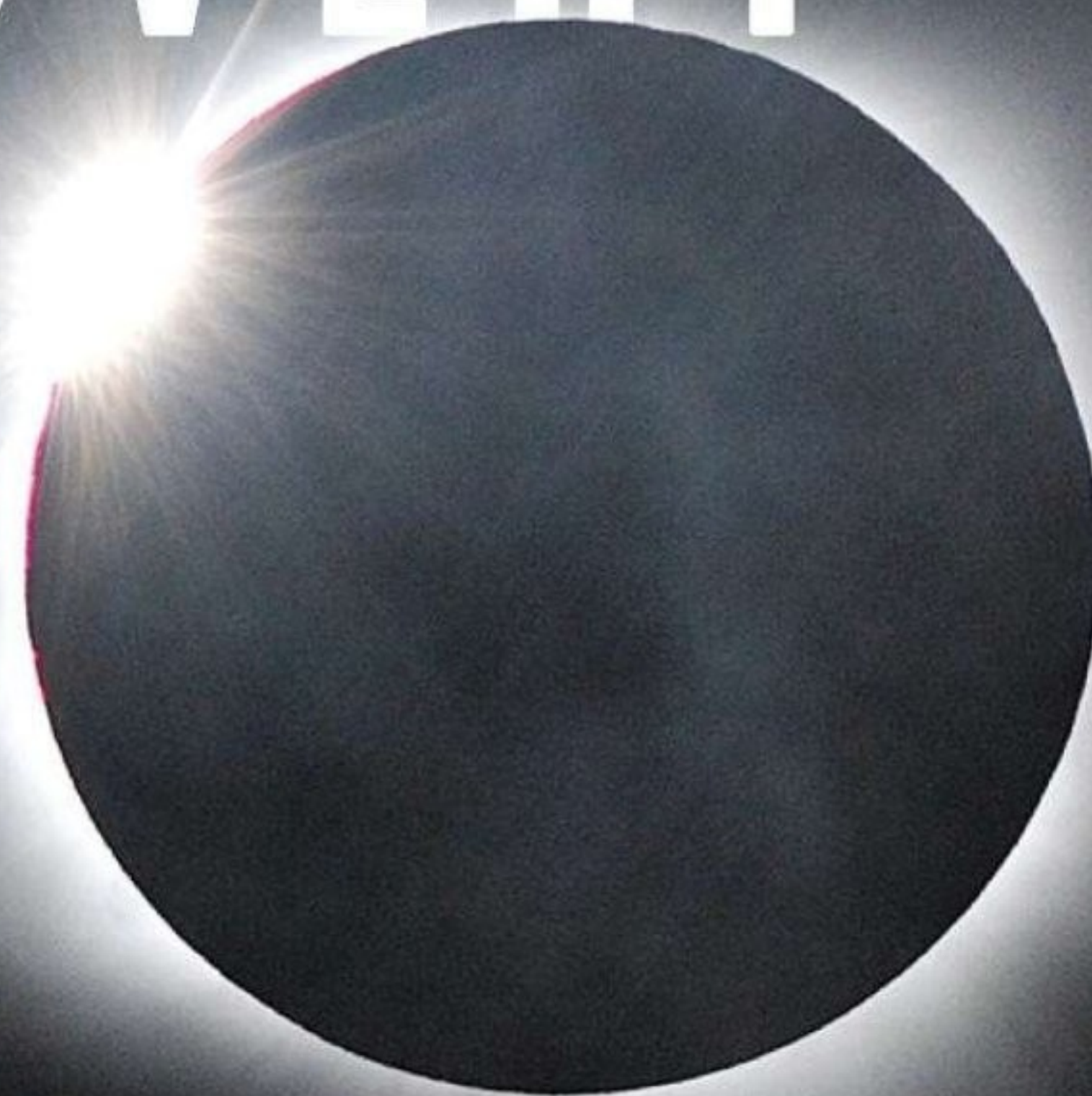


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INSIGHT Interpreting physics

Don't discard any quantum options

Michael Brooks

IT'S time to put all the quantum cards on the table. That's the view of a group of physicists who assembled in Vienna last month to present a variety of ideas, results and plans for future experiments that might help find an explanation for the weirdness of quantum theory.

Quantum physics is well known for being weird. The theory – and the experiments that have confirmed it – rip gaping holes in our concept of space, time and reality. Most physicists simply accept this as the way things are. But most of the 70 or so researchers who

"Many people think they are along the path to better understanding, but they all contradict each other"

gathered in Austria at the Vienna symposium on "Emergent Quantum Mechanics" from 23 to 25 October were there to go deeper, and ask where the quantum laws might come from. Is quantum physics a stepping stone to a deeper understanding of reality?

"There are many people who think they are well along the path to a better understanding, but they all contradict each other," says Aephraim Steinberg of the University of Toronto, Canada. "So maybe one of them is right – but I certainly don't know which one."

Steinberg presented experiments that attempt to show the paths photons take as they appear to pass simultaneously through two slits. This is because of quantum superposition – a trick in which the photon seem to be in two

different states at once. The most widely accepted interpretation of quantum theory claims that this is possible because the photons only have definite properties once they have been detected. Before that, there is only a mathematical wave function describing possible outcomes of the measurement.

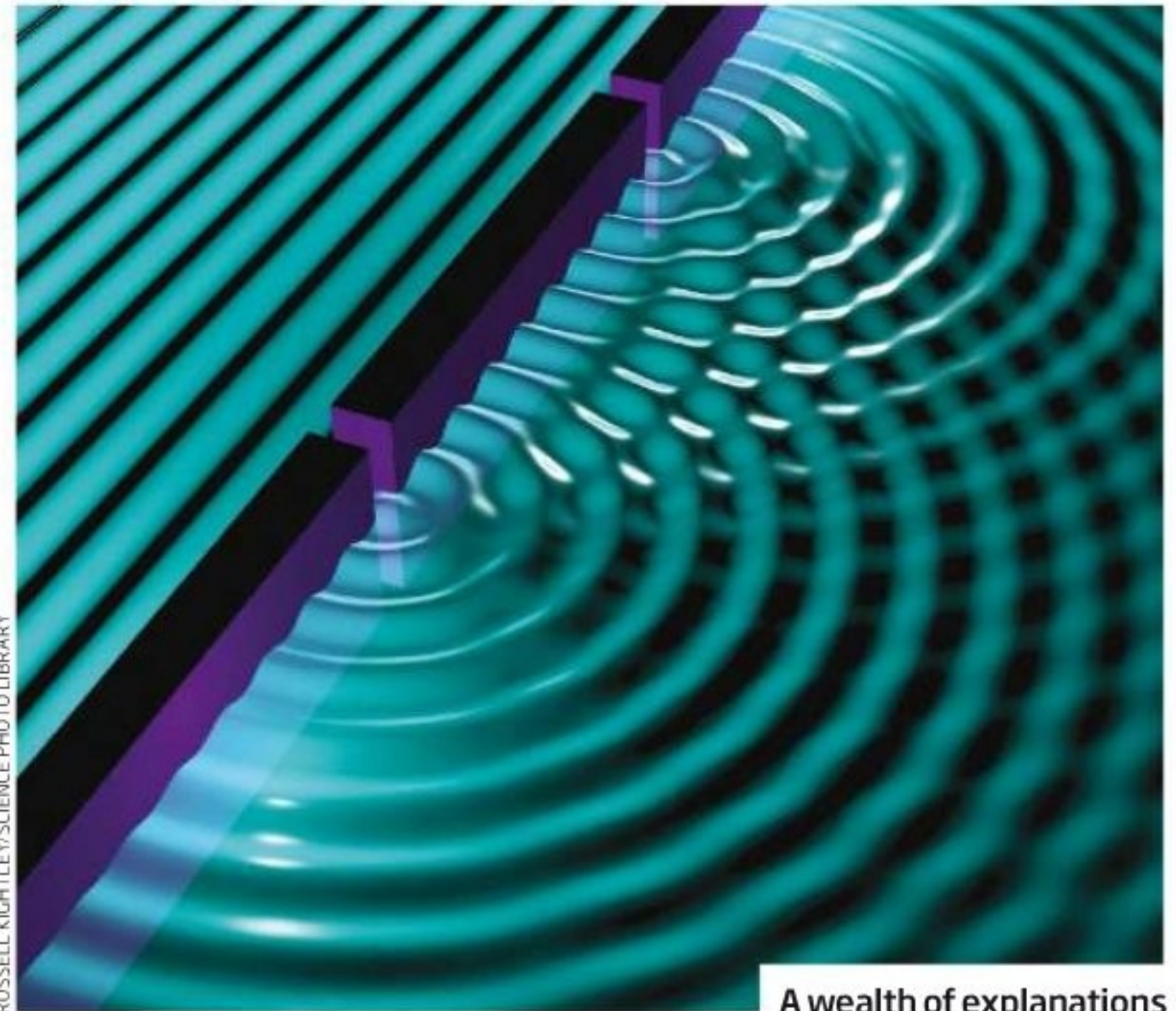
But Steinberg prefers to interpret the experiment in terms of so-called Bohmian mechanics, which suggests that there are pre-existing connections between all quantum particles. Each particle has an associated "pilot wave" that guides its position and momentum, so it takes a particular trajectory through the double slits. "These are very straightforward experiments that draw a connection between that model and what happens in the real world," he says.

Many find Bohmian mechanics unsatisfactory. But discussions at the meeting made it clear that the same can be said of most interpretations – and it was.

Lev Vaidman of Tel Aviv University in Israel, for instance, told the gathering that they were



Competing theories



A wealth of explanations

on a wild goose chase. "There is no reason to go deeper," he said.

However, Vaidman has his own favourite theory: he is a fervent advocate of the Many Worlds interpretation. This suggests that each quantum event – such as a photon forced to choose between two slits – is a trigger for a new universe to open up. The photon goes through one slit in one universe, and the other slit in the other. He says that is the only way to explain why measurement appears to "collapse" a superposition of states.

Markus Arndt of the University of Vienna is investigating that same problem by putting ever bigger and more complex molecules, including vitamins, into superpositions. He suggests that as the molecules become more complex, their internal configurations may change when they collapse, giving us an insight into what lies behind it.

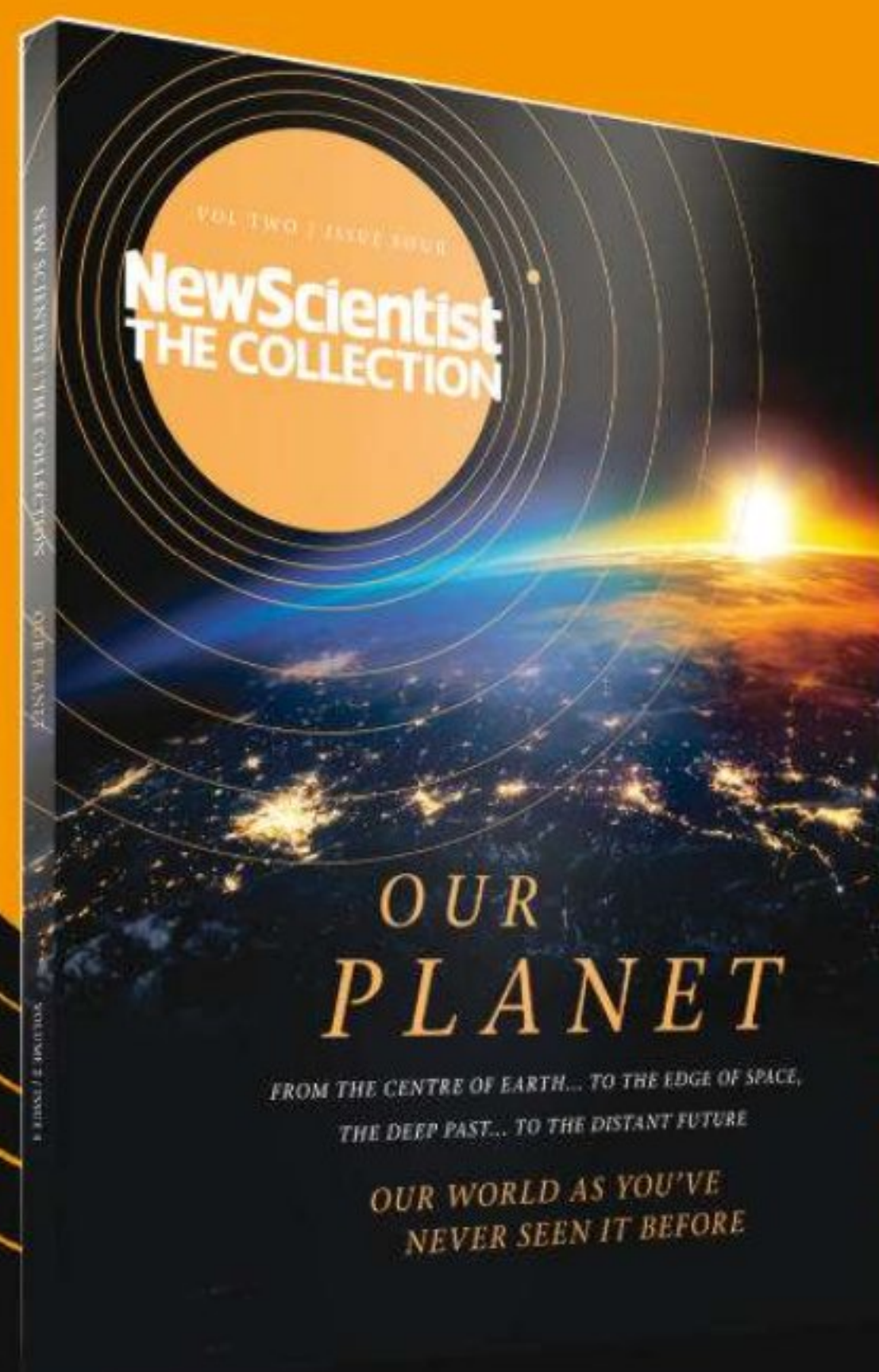
Nobel laureate Gerard 't Hooft thinks things are simpler than that. "I don't have to go through all the gymnastics," he said. He has developed an interpretation called superdeterminism, which suggests that the physical world

has hidden connections that formed during the processes that created its particles and fields, as opposed to simply existing. These connections lie behind the weird phenomena and the apparent randomness of quantum effects.

Did the meeting get us anywhere? 't Hooft thinks so, but selfishly. "It allows me to explain my vision to people," he says. "I'm becoming more and more convinced that I'm right."

More altruistically, Howard Wiseman of Griffith University in Brisbane, Australia, points out that keeping all the possible interpretations in mind helps seed new ideas. "It's all part of the scientific discussion," he says. "It makes a difference to the sorts of experiments you think about doing."

Meeting organiser Jan Walleczek of Phenoscience Laboratories, an independent research organisation based in Berlin, Germany, agrees. "I believe the meeting was highly effective in drawing attention again to neglected possibilities," he says. "We believe that a new chapter in quantum foundations research has opened up." ■



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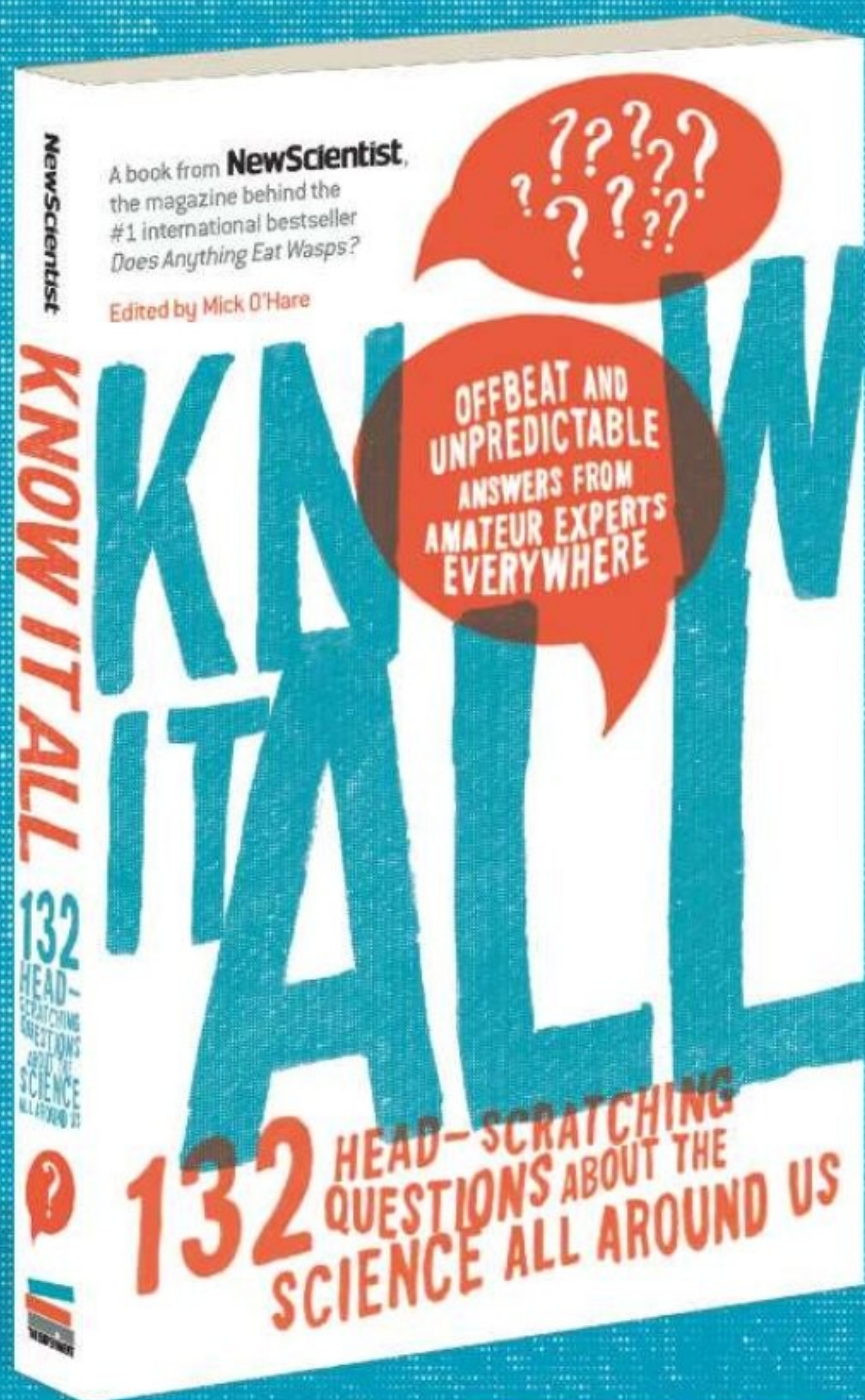
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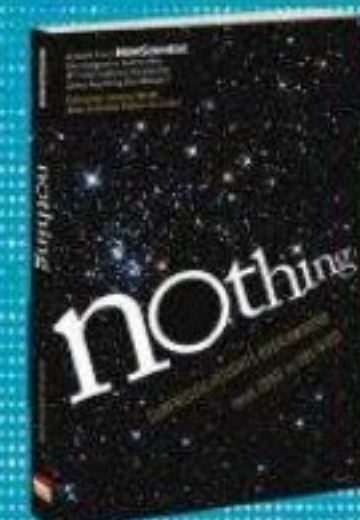
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Growing corals bathe in acid, confounding expectations

HERE'S a surprising twist. Acidic water may actually be a sign of healthy corals, says a new study, muddying the waters still further on our understanding of how coral reefs might react to climate change.

Andreas Andersson of the Scripps Institution of Oceanography in San Diego, California, and his colleagues carefully monitored a coral reef in Bermuda for five years, and found that spikes in acidity were linked to increased reef growth (*PNAS*, DOI: 10.1073/pnas.150721112). "It's completely the opposite to what we would expect in an ocean-acidification scenario," says Andersson.

The team discovered that the coral growth itself drove up this local acidity. To build their skeletons, it seems the corals sucked alkaline carbonate out of the water, leaving it more acidic.

The results complicate the question of how coral reefs will respond to climate change, which is raising the acidity of the oceans. "Do corals care about ocean pH if they have plenty of food and light? At this point, we don't fully know the answer to that question," says Andersson.

These corals didn't seem to mind the fluctuations in local acidity that they created, which were much bigger than those we expect to see from climate change. This may mean that corals are well equipped to deal with the lower pH levels caused by greater acidity.

Gut bugs influence cancer treatment

HOW well a cancer treatment works might depend on what's living in your gut.

Mathias Chamaillard at the University of Lille, France, and his colleagues discovered that the skin cancer drug ipilimumab isn't as effective at treating cancer in mice born without bacteria in their gut, compared with mice with normal bacteria. The drug's effectiveness also decreased when the normal

mice were given antibiotics to wipe out their gut bacteria.

Ipilimumab appears to cause a decrease in two types of gut bacteria, called *Bacteroidales* and *Burkholderiales*, suggesting these bacteria interact with the drug.

The team took faecal samples from 25 people with skin cancer and tested them for levels of *Bacteroidales*. When they transplanted the samples into

mice without gut bacteria and gave them ipilimumab, those that received transplants containing more *Bacteroidales* responded better to the treatment (*Science*, doi.org/83s).

Chamaillard believes the bacteria are influencing the immune system in a way that facilitates the drug. He now plans to test whether the profiles of bacteria living in someone's gut can predict how well they will respond to cancer treatment.

Have pincers, will grab ride on a bat

WHAT'S a tiny invertebrate to do? Getting around can be a struggle when you're only a few millimetres long, but the jet-setting pseudoscorpion *Apatochernes vastus* has the answer: hitch a ride on a bat.

These arachnids have two large pincers like scorpions do, but no stinging tail. Many species use their pincers to deliver venom to small prey, including insects.

But these huge appendages have another use – clinging onto larger animals. "Hitch-hiking is their best way to disperse," says Graeme Finlayson at Massey University, New Zealand.

Pseudoscorpion species around the world have been found stowing away aboard a variety of animals, and now *A. vastus* has been spotted travelling by bat in New Zealand (*New Zealand Journal of Zoology*, doi.org/833). "They just grab on to the fur and then off they go," says Finlayson.

Cage traps light but lets liquid through

PHOTONS keep out! Microscopic cages could be built to block light, while letting liquid and gas flow.

Boxes can shield objects from light, but when accessing the contents, light slips through any holes you make. That's a problem for proposed medical techniques using targeted light to control drug release. Now Ali Mirzaei of the Australian National University in Canberra and his colleagues may have a solution: "optical metacages" made from ultra-thin wires.

The team simulated a wire 200 nanometres wide and found it absorbed light from up to 100 nanometres from its edge. Placing wires at intervals would make cages that stop light going in or out (*Physical Review Letters*, in press).

Planetary billiards makes hot worlds

WORLD creation is only a game. Planetary billiards might have built exoplanets known as hot Jupiters.

Most of the first exoplanets found were hot Jupiters: gas giants that orbit close to their stars. Early theories proposed they formed far away, then moved inward. But then large, rocky worlds were spotted orbiting near their stars, making it more likely that hot Jupiters also formed closer in.

But how? Aaron Boley of the University of British Columbia in Canada and colleagues have an idea. Sometimes a few rocky planets are packed close to their star; most of these systems will become unstable, and the planets will crash into one another. If those collisions occurred slowly enough, suggest Boley's team, the planets could stick and form the core of a new planet. And if there was gas and dust around the star, that core could grab on to enough of it to become a hot Jupiter.

To find out, the team added instabilities to a computer model of Kepler-11, a system that contains six rocky planets orbiting closer to their star than Mercury does to the sun. The simulations produced several warm Jupiters – gas giants just a bit further from their stars than hot Jupiters (arxiv.org/abs/1510.04276). The team thinks different configurations of planets could result in the hot gas giants.



DETLEV VAN RAVENSWAAY/SCIENCE PHOTO LIBRARY

Coming soon: first weather report from super-Venus planet

WE JUST found the planetary equivalent of Darwin's first finch. GJ 1132b is the first in a new class of rocky planets close enough to study in depth with today's technology – signalling that exoplanet studies are about to become more than mere stamp collecting.

First spotted with the ground-based M-Planet telescopes this May, the new planet orbits a cool star just 40 light years away and is slightly larger than Earth, with about 60 per cent more mass. That suggests it's a rocky world

like ours. But GJ 1132b hugs its star closely, orbiting once every 38 hours, giving it a temperature somewhere between a few dozen and a few hundred degrees too hot to have liquid water (*Nature*, DOI: 10.1038/nature15762).

That heat makes it more like a super-Venus than a super-Earth. But GJ 1132b is exciting because the Hubble Space Telescope should be able to analyse the chemicals in its atmosphere with relative ease, says M-Planet team member Zachory Berta-Thompson at the Massachusetts

Institute of Technology.

Either Hubble or its successor, the James Webb Space Telescope set for launch in 2018, will hopefully show us which chemical compounds are in the planet's atmosphere – a major step towards understanding whether the atmospheres of similar worlds just a little further from their stars could be hospitable to life.

"This is maybe the first rocky exoplanet we can really characterise in the next decade," says Rory Barnes of the University of Washington in Seattle.

Backward step for Alzheimer's drug

HELPFUL or harmful? It seems as if antibody drugs used to get rid of sticky plaques that build up in brains with Alzheimer's may actually make the disease worse. In mice with a version of Alzheimer's, the antibodies make brain cells hyperactive, and the cells ultimately die.

"We think this is a possible mechanism for the failure of these antibodies in human trials," says Marc Busche of the Technical University of Munich, Germany.

Busche and his colleagues found that mice with Alzheimer's that were treated with antibodies had five times as many hyperactive brain cells as treated normal mice. And in those with early-stage disease, the antibodies not only made cells hyperactive but also made symptoms worse – even before the mice developed plaques (*Nature Neuroscience*, DOI: 10.1038/nn.4163).

Other researchers caution that mouse studies have a history of misleading results. "Mouse models are not perfect – we've been curing animals of Alzheimer's for years," says Maria Carrillo, chief scientific officer of charity the Alzheimer's Association.



PAUL D. STEWART/SPL

Missing mineral equals mass extinction

MIND you get your minerals. Could a lack of essential trace elements in the world's oceans be the cause of most of Earth's mass extinctions? A new theory suggests that marine animals, from plankton to reptiles, succumbed to such fatal deficiencies.

Earth has been hit with five mass extinctions, three of which we can't explain. Earlier this year, researchers discovered that periods when the ocean had high levels of trace elements – like zinc, copper, manganese and selenium – seemed to overlap with periods of high productivity, including the Cambrian

explosion, when most groups of living animals first appeared.

Now new research shows that drops in selenium correlate well with each of the extinction events at the end of the Ordovician, Devonian and Triassic periods (*Gondwana Research*, doi.org/834).

"They're called essential trace elements, because without them we die," says John Long at Flinders University in Adelaide, Australia. "We're not saying this is the whole answer, but it's another factor that correlates with these mass extinctions."

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Surveillance powers proposed by the UK government will damage privacy, and may push criminals into using encryption, finds **Jacob Aron**

THE UK government wants your web history. Surveillance powers proposed by the Home Office last week have come under fire from privacy advocates for putting innocent people's personal data at risk. The proposed law may even spark a wave of encryption, making it more difficult for the police and security services to find criminals and terrorists.

If passed into law, the Investigatory Powers Bill, presented to Parliament on 4 November, would require internet service providers (ISPs) to keep a record of every website their customers visit, storing each for 12 months. It would also create a legal basis for the government to survey phones and computers on a large scale, and read encrypted messages sent through online services – activities that documents revealed by Edward Snowden suggest the government was already doing.

The bill is meant to bring the power to track online communications in line with the government's ability to monitor landlines and cellphones. "It cannot be right that today the police could find an abducted child if the suspects were using mobile phones to coordinate their crime, but if they were using social media or communications apps then they would be out of reach," UK home secretary Theresa May said in her speech presenting the bill. Police say their inability to look into online services has already stymied some investigations.

Authorities will only be able to access internet connection records – root addresses like newscientist.com, along with the time and date of the visit – for

three reasons: to identify the sender of a communication, to identify the apps or services they are using, and to determine whether or not someone has accessed illegal material. Once they know which sites someone is using to communicate, they can request more complete details from the site or service involved.

The goal is to apply the existing model of investigation, in which phone records are used to reveal

"This will get ordinary people doing ordinary things, it won't get the criminals or terrorists"

patterns of communication, to the digital age. But Eerke Boiten of the University of Kent, UK, says the websites we visit are far more revealing than the numbers we call: "If I go to a website about a rare disease, that says a lot more than if I have a phone call with my GP." Collecting everyone's browsing history also puts innocent people at risk, he adds (see "Your browsing life", below).

It's not even clear that the plan is technically feasible. The UK government says it will pay ISPs £175 million over the next 10 years

to cover the cost of collecting and storing internet communication records. Sky and BT, leading ISPs in the UK, declined to comment on how this would be achieved when asked by *New Scientist*, but Adrian Kennard, managing director of specialist ISP Andrews & Arnold, says it isn't as simple as keeping phone records.

Unlike a call routed from one person to another, accessing a website can involve sending hundreds or thousands of packets of data, and the web address won't be in all of them.

"It's technically very difficult to put together the sequence of packets from a customer that identifies they are visiting a website," says Kennard. "Large ISPs have a vast amount of data going across their network. To comply with this they may have to send every single one of those packets, millions or billions a second, through some system to work out what is going on. It's not going to be cheap."

Even with the added expense, recording web traffic may not be worthwhile. "This will get ordinary people doing ordinary things, it will not get the serious criminals, the serious terrorists,"

YOUR BROWSING LIFE

Your web history says a lot about you. The sites you visit can reveal sexual orientation, religious beliefs, details about your health – and lots more.

The UK government says it won't look at this information, but if the draft Investigatory Powers Bill proposed last week becomes law, it will have access to it. Powers meant for stopping terrorists have been used to catch people who let their

dogs foul public spaces, so there is precedent for data to be misused.

What's more, if an ISP storing this data is hacked, as TalkTalk was recently, it could harm millions of people. "It certainly becomes a very attractive target for hackers, if they can get the web browsing history of every single person in the country," says Kenneth Paterson of Royal Holloway, University of London.

says Paul Bernal, who researches internet privacy law at the University of East Anglia, UK. Savvy criminals already use encryption and software like Tor to hide their online activities, so storing web records won't help combat this.

It could also push lower-level criminals, along with people concerned about their privacy, into using encryption and Tor, making the police's job more difficult. "I think that's entirely likely," says Bernal. "The more people use those, the harder it is to find people using them who are potentially dangerous."

The government has attempted to prevent this by clarifying an existing legal power requiring communication service providers to remove any encryption they apply to users' messages when asked by authorities. However, it's not yet clear what this will mean for end-to-end encryption services like the Android version of Facebook's WhatsApp, and Apple's iMessage. These use a long number called a key, stored on the



SAM EDWARDS/PLAINPICTURE



What are you looking at?

user's device, to scramble messages in a way that only the recipient can read. These encrypted messages cannot be decrypted by Apple or Facebook because they don't hold the keys.

Kennard compares the government's plan to the overuse of antibiotics – it may end up leaving only resistant strains that are harder to fight. "If enough stupid criminals go to jail because they aren't smart enough to use iMessage, the rest will start using it," he says. It's also possible to run your own encryption without a service provider like Apple, so it can't be banned outright.

These issues mean the government should abandon plans to collect web history, says Bernal. "Mass systems get the masses, they don't get the ones they really want," he says. "The approach should be much more intelligent."

Hacking specific phones and computers is a more precise way to intercept someone's communications. The bill clarifies police and security services'

power to do this "equipment interference". But that kind of hack, which requires a warrant, relies on fundamental flaws in software or hardware, either bugs overlooked by manufacturers or introduced at a government's request. If the UK government finds or introduces such flaws, then others can find and exploit them too, putting everyone at risk. GCHQ, the UK's digital spies, does assist companies in patching vulnerabilities, but Snowden's files reveal they also keep some back for use in their hacking arsenal.

Adapting investigatory powers for the digital age is crucial, but the complexities of doing so and the potential for harm can't be ignored. "What we do now will probably set the agenda for surveillance for the next couple of decades. We have to be thinking of where things are moving, not just how it is written right now," says Bernal. "Where there are gaps or vagueness in the law, the snoopers take advantage of those and stretch the limit." ■

Pimp your old stuff by 3D printing over it

3D PRINTING is going to change the world, we're told. But it sometimes seems that all we can print is useless plastic tat – or perhaps, if you're lucky, a fiddly replacement bit for the dishwasher.

But a new technique is giving 3D printing the power not just to create novel objects, but to augment and repair things we already own. It should make 3D printing far more useful.

To use Encore, a 3D printing system developed by Xiang Chen and his colleagues at Carnegie Mellon University in Pittsburgh, you must first design the section you want to add to an object. The software then scans the object you want to modify. It analyses the surface geometry and texture to see where additions can be printed. It then prints the desired extra piece on or around the object.

The team has already used Encore to print the housing and components of a torch around a 9-volt battery, mount a plastic teddy bear on a fridge magnet, to print a handle on a cup and a holder for a four-pack of cans.

Instead of ushering in a world of endless, cheap replacements for our stuff, 3D printing systems like Encore may help us extend the value of the things we already own.

"I think people have long been frustrated that every time we start a 3D printing job we always have to

start from scratch," says Chen.

A similar project from Stefanie Mueller and her colleagues at the Hasso Plattner Institute in Potsdam, Germany, takes the idea a step further. As well as adding to existing objects, it can mill away redundant sections of an object, then print updated designs in their place.

Mueller's team has used the system to print a holder for a smartphone when the old one broke, and to change the holder to fit a larger phone when the phone was upgraded. It is

"I think people have long been frustrated that we always had to start a 3D print job from scratch"

due to be presented this week at the Symposium on User Interface Software and Technology in Charlotte, North Carolina.

"3D printing is on the verge of becoming a mass-market," says Mueller. Technology analysis company Gartner estimates that about 250,000 consumer printers will be sold in 2015, up from just 35,000 in 2012. It also projects that more than a million will be sold in 2017.

"Everyone will own a 3D printer in the future, once we have solved the challenges," says Mueller.

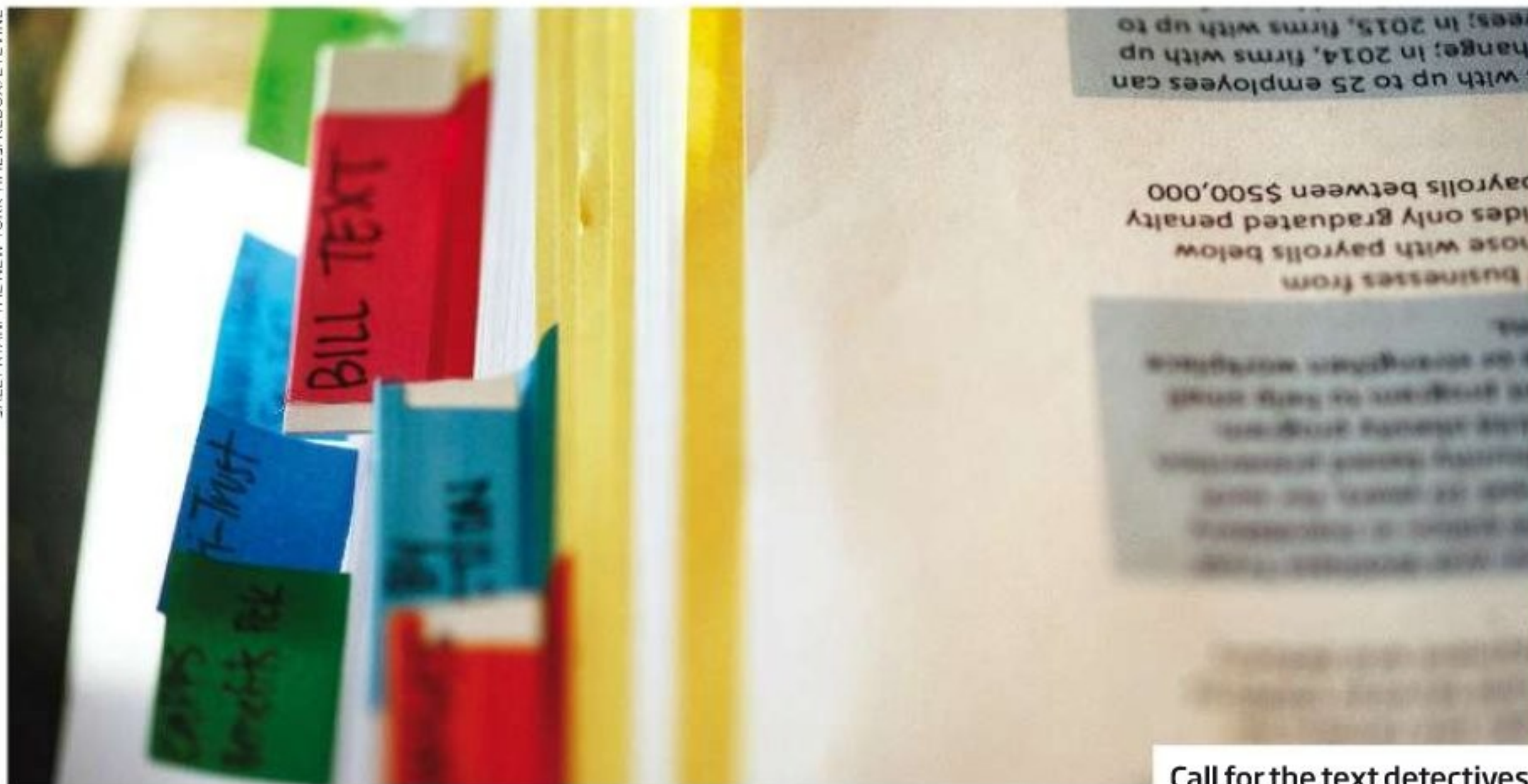
Hal Hodson ■



That magnet is unbearable

TECHNOLOGY

SALLY RYAN/THE NEW YORK TIMES/REDUX/EYEVINE



Call for the text detectives

Law influencers unmasked

Software is now holding politicians to account, finds **Aviva Rutkin**

POLITICIANS beware. Software can scrutinise legislative bills, working out the source of the text. It could allow voters to see who actually determines what goes into bills.

There is a long history of companies and other vested interests influencing legislation by lobbying politicians. So researchers at the University of Chicago's Data Science for Social Good programme have created the Legislative Influence Detector. This scours the text of US bills, searching for passages that have been cribbed from lobbyists or the legislatures of other states.

"Our hope is that the public can use this to keep the government accountable," says team member Julian Katz-Samuels, now a graduate student at the University of Michigan.

To get the real story behind a bill, the software digs through 500,000 state bills, as well as thousands of pieces of text drafted by lobbyist groups that were saved into a database. An algorithm then calculates the top 100 documents most relevant to the bill in question before

examining each one more closely, searching for passages the two have in common.

What this reveals can be telling, says Katz-Samuels. The software can turn up lines of text originally written by activists and special interest groups. Or it might find that the bill borrows largely from laws already in place elsewhere,

"The software can turn up lines of bill text originally written by activists and special interest groups"

giving concerned citizens the chance to explore how the policy worked out there.

In one example, the researchers ran the detector on Wisconsin Senate Bill 179, a bill passed in June that bans non-emergency abortions after 20 weeks. The team found that the bill's passage on fetal development – which pinpoints 20 weeks as the point when fetuses could feel pain – had appeared in one form or another in a handful of other proposed abortion bills across the country. Further digging traced the text back to an anti-abortion

organisation's website, with the group appearing to be the original author of the text.

"Since these bills are tangled up in policy schemes, we need better methods for untangling them," says David Smith at Northeastern University in Boston, who has studied how text from failed bills gets reused in later legislation by US Congress.

The detector is the latest in a string of projects that try to use computers to hold governments to account. At the University of Texas at Arlington, computer scientist Chengkai Li is building a system to fact-check the statements of politicians in real time. The ClaimBuster, as he's calling it, will study work done by human fact-checkers and, with the help of machine learning, start automating some of that process.

Li envisions a final platform that can scan through the transcript of a speech or presidential debate, picking out the lines that we already know to be true or false so journalists can work on checking more complicated claims. ■

ONE PER CENT

Loser apps

Put down the phone... and the chocolate bar. Smartphone apps alone aren't that effective at helping people lose weight. Researchers at Duke University in Durham, North Carolina, asked 122 overweight people to track their diet, weight and exercise with an Android app. After two years, the app users and a control group had lost the same amount of weight – just 0.9 kilograms, on average (*Obesity*, doi.org/85q).

"We're in stealth mode where we're not revealing ownership"

Start-up Faraday Future says it is building a \$1billion factory for electric cars, amid speculation that Apple or a Chinese billionaire is behind it.

Ghost house

From my kitchen to yours. An invention called "Ghosting" syncs sound and light between houses. When someone turns the lights on in one kitchen, they automatically switch on in the connected house. Sounds are picked up and relayed, too. Engineers at the University of Michigan successfully linked an apartment in Michigan with one in Maryland. The work was presented at the IoT-App conference in Seoul, South Korea, last week.



IMAGE SOURCE/GETTY



A career in science, it's not always what you think

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festival director, where will your
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NewScientist







Icy survivors

THE cold war forgot about these relics. These images, taken by photographer Danila Tkachenko in Russia and Kazakhstan, show bold attempts at technological progress that were abandoned. Tkachenko ventures out into the snowy wastes to document the deserted remains.

The main image shows a Bartini Beriev VVA-14, an aircraft developed by the Soviet Union in the 1970s. Designed to take off from water, the idea was to fly low over the sea and destroy US submarines. Only two were ever built, and one crashed. This dilapidated survivor resides in Russia's Central Air Force museum.

On the right, centre, is the location of a nuclear contamination test in a lake close to the site of the Kyshtym nuclear disaster. In 1957, an explosion occurred at a plutonium production plant, releasing about 80 tonnes of radioactive material. Details of the accident were kept secret until 1976, when dissident Soviet scientist Zhores Medvedev wrote about it in *New Scientist*. The nearby city of Ozyorsk remains inhabited but access is restricted; Tkachenko was able to enter because his grandmother lives there.

Below and above are remnants of the space race: parts of a rocket and an unfinished space port in Kazakhstan, close to the Baikonur Cosmodrome where Yuri Gagarin launched on the first crewed space flight in 1961. Sam Wong

Photographer

Danila Tkachenko

danilatkachenko.com

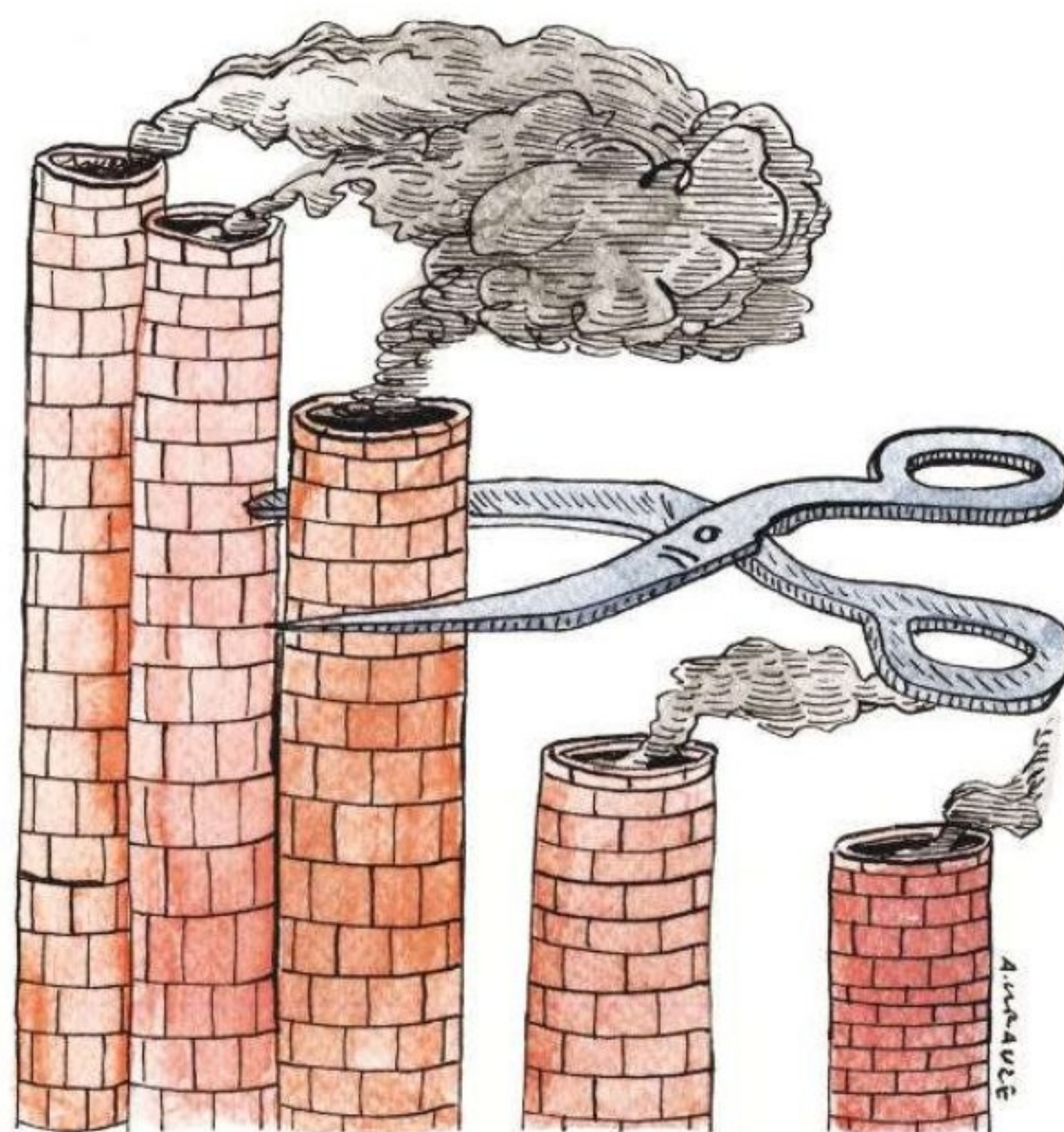
Paris can cut it

Crunch climate talks can be a success even without a deal to keep warming below 2 °C, says **David Victor**

LATE this month, the curtain rises on a global summit in Paris aimed at mitigating the prospect of damaging climate change. Over the past year, governments have been making pledges about how they will cut emissions, and one of the main outcomes from Paris will be a new agreement that codifies all those national efforts into international law.

Critics are already sounding alarms that the outcome will be too little and too late. Even if all the individual pledges are met, the planet will keep on warming – almost certainly past the internationally agreed threshold of acceptable risk, 2 °C above pre-industrial temperatures.

But these critics miss the point. What's new about Paris isn't that it will cap the rise at 2 °C. That has not been feasible for years; emissions of warming gases have



been rising steeply since 1990 when the search for a deal really began. No, Paris matters because it is likely to set a foundation for governments to coordinate policies on emissions while also helping countries adapt to the big climate changes in store.

The Paris pledges already put the world on track for a lot less warming than some feared a few years ago. And governments in richer countries are on track to honour a commitment to free up, by 2020, about \$100 billion per year to help the poorest countries.

Much of this success comes from the system of individual national pledges. It has given countries flexibility to focus their obligations on areas where they are willing and able to act. Most emissions growth is in developing and emerging economies, which are wary of rigid, binding controls. These nations are more

Keeping our cool

It's still possible to stop global warming from busting the accepted limit, says **Bob Ward**

CLIMATE scientists can be a gloomy lot, but the professional pessimism of some is in danger of seriously misleading politicians.

Ahead of the crucial UN summit in France, more than 150 countries have submitted pledges for climate-change mitigation after 2020. An assessment of these suggests

that global annual emissions of greenhouse gases in 2030 will equate to between 55 and 60 billion tonnes of carbon dioxide.

This has led some climate scientists to declare that staying below the 2 °C warming limit, and hence avoiding dangerous climate change, is impossible. But the evidence indicates that it is

achievable, even without large-scale negative-emissions projects, such as bioenergy with carbon capture and storage.

The *Emissions Gap Report 2014*, published by the UN Environment Programme, analysed scenarios outlined in the *Fifth Assessment Report* of the Intergovernmental Panel on Climate Change. It found 16 scenarios that resulted in a 50 to 66 per cent chance of avoiding warming beyond 2 °C, all with no need for negative emissions and

assuming moderate mitigation efforts began in 2010 and are not delayed until after 2020.

These require annual emissions to drop from the current 50 to 53 billion tonnes to a median of 37 billion tonnes by 2020, 36 billion by 2030, 27 billion by 2050, and 14 billion by 2100. This is technically plausible, even if it needs more action than is planned.

Governments recognise the gap between present commitments and an emissions pathway that avoids dangerous climate change. It is likely that the Paris agreement will initiate a process through which countries will ramp up the scale of cuts, acknowledging that

"Scientists must shelve cynicism about the political will to tackle climate change"

comfortable with a flexible system and, as a result, they have engaged more fully with international efforts.

Despite this optimism, it is still possible that diplomats will grab defeat from the jaws of victory. The biggest threats to securing a deal don't come from countries that want to water it down – instead they come from countries frustrated that the world's top emitters haven't done enough.

Such nations are already being damaged by climate change and rightly argue that they shouldn't bear the costs. They have a long list of impractical demands for more money and even steeper cuts in emissions in richer nations, plus unfeasible warming limits such as 1 or 1.5 °C.

Deep greens will call Paris a failure. But it could do more to establish practical mechanisms for cooperation than any other deal since the early 1990s. It would, of course, have been better for this to have happened long ago. But better late than never. ■

David Victor is professor of international relations at the University of California, San Diego. He chairs the Global Agenda Council on Governance for Sustainability at the World Economic Forum and is author of *Global Warming Gridlock* (Cambridge University Press)

what is on the table now should be a floor, not a ceiling, for reductions.

Scientists must shelve cynicism about the political will to tackle climate change. Instead they must help governments, the public and businesses understand what must be done to have a reasonable chance of staying below 2 °C.

Otherwise there is a danger that politicians may get the mistaken impression that evidence shows this is impossible, and will stop trying to meet this crucial goal. ■

Bob Ward is policy and communications director at the ESRC Centre for Climate Change Economics and Policy at the London School of Economics

ONE MINUTE INTERVIEW

Star maker

I want people on the street to be fans of scientists, not just entertainers, says billionaire internet investor **Yuri Milner**



PROFILE

Tech investor and physicist Yuri Milner launched the Breakthrough prize to create scientific heroes for the next generation. Seven prizes of \$3 million each were awarded at the prize ceremony on 8 November

We spoke to you in 2013 at the launch of the Breakthrough prize. What's your verdict so far?

We have a long way to go. The idea of the Breakthrough prize is to raise awareness of fundamental science. A simple test is to ask someone in the street to name a living scientist. They can name plenty of entertainers, but still no scientists.

Why are you so keen to promote fundamental science?

It's important to remember that everything around us came from scientists, not engineers. Twenty-five per cent of the world's GDP originates from quantum mechanics, which was a very abstract theory 100 years ago. If you go far enough into the future, a fundamental discovery leads to some new technology.

How do you turn scientists into heroes?

There are many different ways, and one of these is our prize-giving ceremony. The Oscars and

Emmys play a big role in popularising the field of acting. We are trying to do the same with our prize, though we apply a rigorous scientific process to it too.

Tell me about the prize ceremony.

It was at the NASA Ames Research Center, hosted by *Family Guy* creator Seth MacFarlane. For the first time it was broadcast live on National Geographic, so more people will see it. If we can eventually reach 50 to 100 million viewers that would inspire young people.

Who selects the winners?

Previous winners pick this year's winners.

All 1300 people who worked on neutrino oscillation experiments were awarded a share in this year's fundamental physics prize. Will they all get a say in future winners?

No, that would be too difficult. But the heads of the five experiments will.

Is it a coincidence that this year's Nobel prize in physics is also for neutrino oscillations?

Yes. We chose our winners in August, well before the Nobel prizes were announced. Inevitably, comparisons are made with the Nobel prizes, but our prize recognises that science is a collective effort and not restricted to three winners at most.

This year you introduced a new prize for high-school children totalling \$400,000. What was your rationale?

These children have no experience of scientific research yet, so we asked 13 to 18-year-olds to make a short video that communicates a complicated idea in science, such as general relativity, in a simple way. It's challenging. The prize will change the winner's life and reward their teacher and school too, but the main message is very important: if someone is interested in science at school, it's cool. Their friends might not think it is at the moment. But it is.

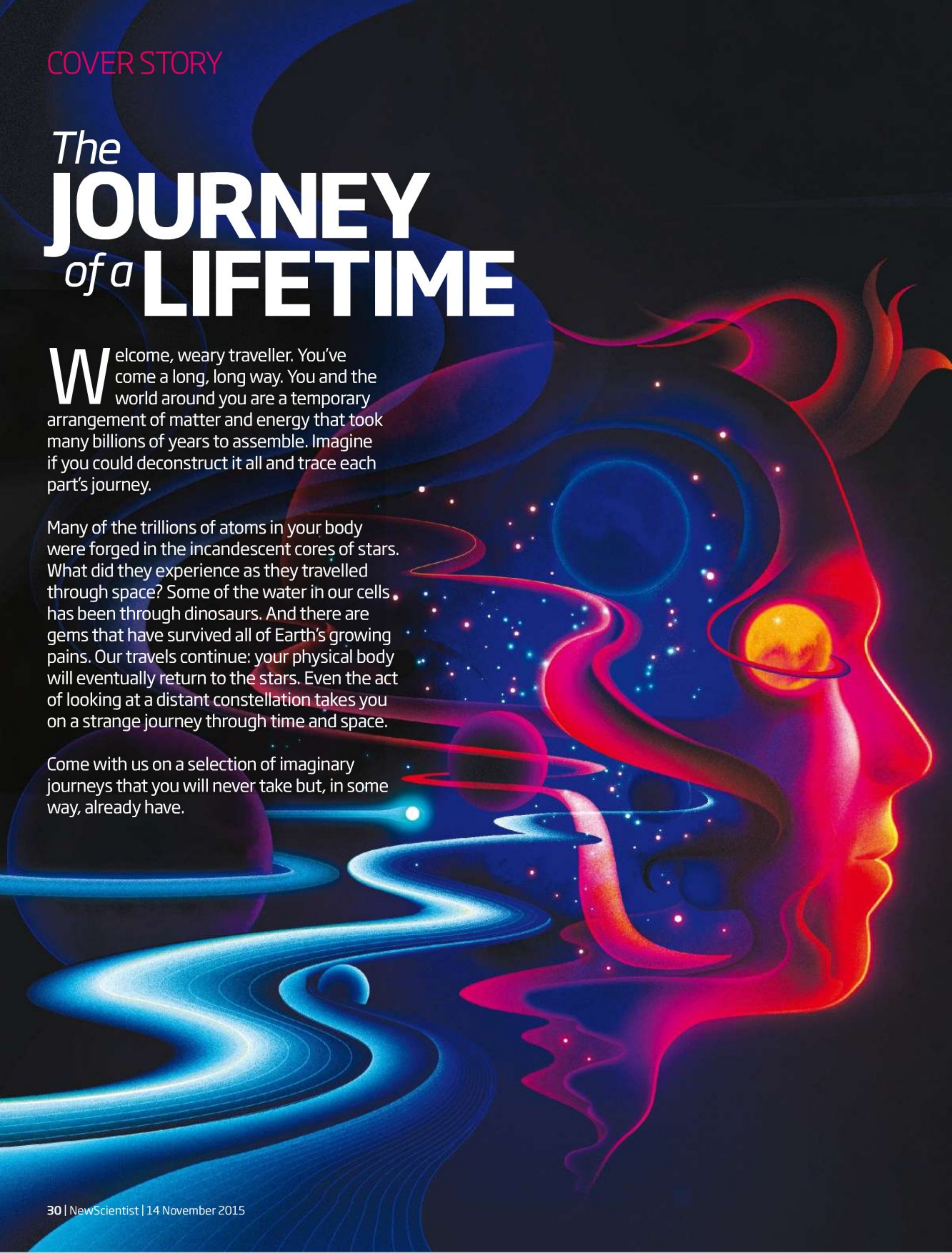
Interview by Valerie Jamieson

The JOURNEY of a LIFETIME

Welcome, weary traveller. You've come a long, long way. You and the world around you are a temporary arrangement of matter and energy that took many billions of years to assemble. Imagine if you could deconstruct it all and trace each part's journey.

Many of the trillions of atoms in your body were forged in the incandescent cores of stars. What did they experience as they travelled through space? Some of the water in our cells has been through dinosaurs. And there are gems that have survived all of Earth's growing pains. Our travels continue: your physical body will eventually return to the stars. Even the act of looking at a distant constellation takes you on a strange journey through time and space.

Come with us on a selection of imaginary journeys that you will never take but, in some way, already have.



STARDUST TO STARDUST

TRAVELLER A calcium atom
ORIGIN The first stars
DESTINATION Your body,
and beyond
DURATION 13.5 billion years+

The calcium in your bones, like every other heavy atom in your body, was forged in the fiery furnace of enormous stars, 10, 100, even 1000 times the mass of the sun. This one, nestled inside your left collar bone, came from one of the universe's very first stars, born 550 million years after the big bang.

When its birth-star burst into a giant supernova, calcium fled the scene like an action hero diving out of an exploding car. It floated through interstellar space for millennia before joining a cloud of gas and dust dense enough to collapse into a new star, also destined to go supernova.

It is a cycle that repeated itself a few times until, some 5 billion years ago, the atom found its way into the cloud that became our solar system. The view from inside the iridescent haze would have been awe-inspiring. Nearby infant stars shone through like floating diamonds, their radiation sculpting the gas and dust into other-worldly sandcastles. Lost in their midst were

all the other atoms that would one day coalesce into your body.

Slowly, the haze contracted under its own gravity, compressing the centre until it was hot enough to ignite into the seed of a star. As the gases swirled around our newborn sun, they dragged the calcium atom into a giant spinning disc.

It took a further billion years for Earth to solidify from the cloud, with your calcium atom trapped inside it. And another 4.5 billion years passed before it ended up in the broccoli you had for dinner the other night. Along the way, it cycled through Earth's crust and oceans, a limestone cliff and a mollusc shell, until finally there it was in the field, sucked into the broccoli plant and onwards to your dinner plate.

You and your collar bone will only be here a short time, as far as the calcium atom is concerned. One day, it will flow out of the bone, into your blood and return to the earth in urine, where it can help other things grow.

In another 5 billion years or so, the calcium atom will look on as the sun collapses into a dense ball of carbon and oxygen, sloughs off the last of its gas and becomes a cool, puffy old star called a red giant. With time, its core will settle into a dense nugget called a white dwarf. The mass of the entire sun will be squashed into a volume about the size of our planet.

If Earth survives this process, it will quickly become a boring, lifeless rock - which shouldn't bother the calcium atom. Eventually, though, Earth may fall onto the surface of the

"Somewhere in the haze were all the atoms that would become your body"

white dwarf. If they bother to look, alien astronomers will see a smear of calcium in the dead star's spectrum. Our own astronomers have recently found similar signs of heavy elements in the spectra of white dwarfs in our galaxy.

But if the outer layers of the sun were to engulf Earth in its death throes and vaporise it... well, it is just possible that the calcium in your collar bone will be carried away as renewed cosmic dust - material for the next generation of stars. Lisa Grossman

ONCE, YOUR BLOOD WAS DINOSAUR URINE

TRAVELLER Water
ORIGIN A comet, smashed into Earth
DESTINATION This page
DURATION 4 billion years

Water's journey began 4 billion years ago when Earth's hellish, dry and volcanic surface was being pummelled by a relentless rain of comets and asteroids. Molecules of water trapped inside them spread across the surface of our planet, and 700 million violent years later, Earth's dry rock had been transformed into the familiar blue marble.

As temperatures rose, a water molecule was swept with billions more into a vast oceanic river that slowly made its way from one pole to the other. For millions of years, the molecule skirted continents, nudged the sea floor, helped to dissolve rocks and transport gases. It crossed the equator hundreds of thousands of times. It found itself at the surface of the sea, was warmed by the sun, rose high into the atmosphere and fell to ground in a raindrop. It seeped through cracks and became stuck in an underground aquifer for centuries. Eventually, as all water does, it found its way back to the ocean.

From 3.8 billion years ago, a new deviation became possible from its usual route cycling around the oceans and atmosphere: inside living cells, keeping them alive.

And so, around 150 million years ago, our molecule finds itself in a lake on what will eventually become one of the great plains of North America. A brontosaurus cranes its neck down for a drink. The water roils around the beast's digestive system and is absorbed into its blood. Now it can perform the most important role Earth has found for it - enabling the basic chemistry of life.

In concert with other water molecules, it forces DNA, proteins and cell membranes into the correct shapes to function. It helps carry oxygen to the dinosaur's brain and shuffles electricity around a heart cell. For a week, it moves around the dinosaur's body, but the game is up once it reaches the animal's kidneys. The molecule is expelled in urine, taking with it some of the brontosaurus's waste. It sinks through ➤

the ground and, like so many times before, finds its way through cracks and fissures and streams back to the oceans.

In subsequent millennia, our molecule finds its way into a whale's brain, an Antarctic ice sheet, a glass of water and a human heart. Later, it waters a pine tree. It sits for decades in the cellulose fibres of the tree's heartwood before the pine is felled and turned into pulp. The molecule stays in place as the pulp goes through chemical reactions, manipulations and dryings until it finds itself locked inside a sheet of paper. That paper is printed with ink. It is cut, folded and stapled. The water molecule sits, motionless, at the end of a sentence, this very one. Alok Jha is the author of *The Water Book* (Headline, 2015)

FROM A SANDWICH TO A SCREAM

TRAVELLER Energy
ORIGIN Your lunch
DESTINATION Your cells
DURATION Hours

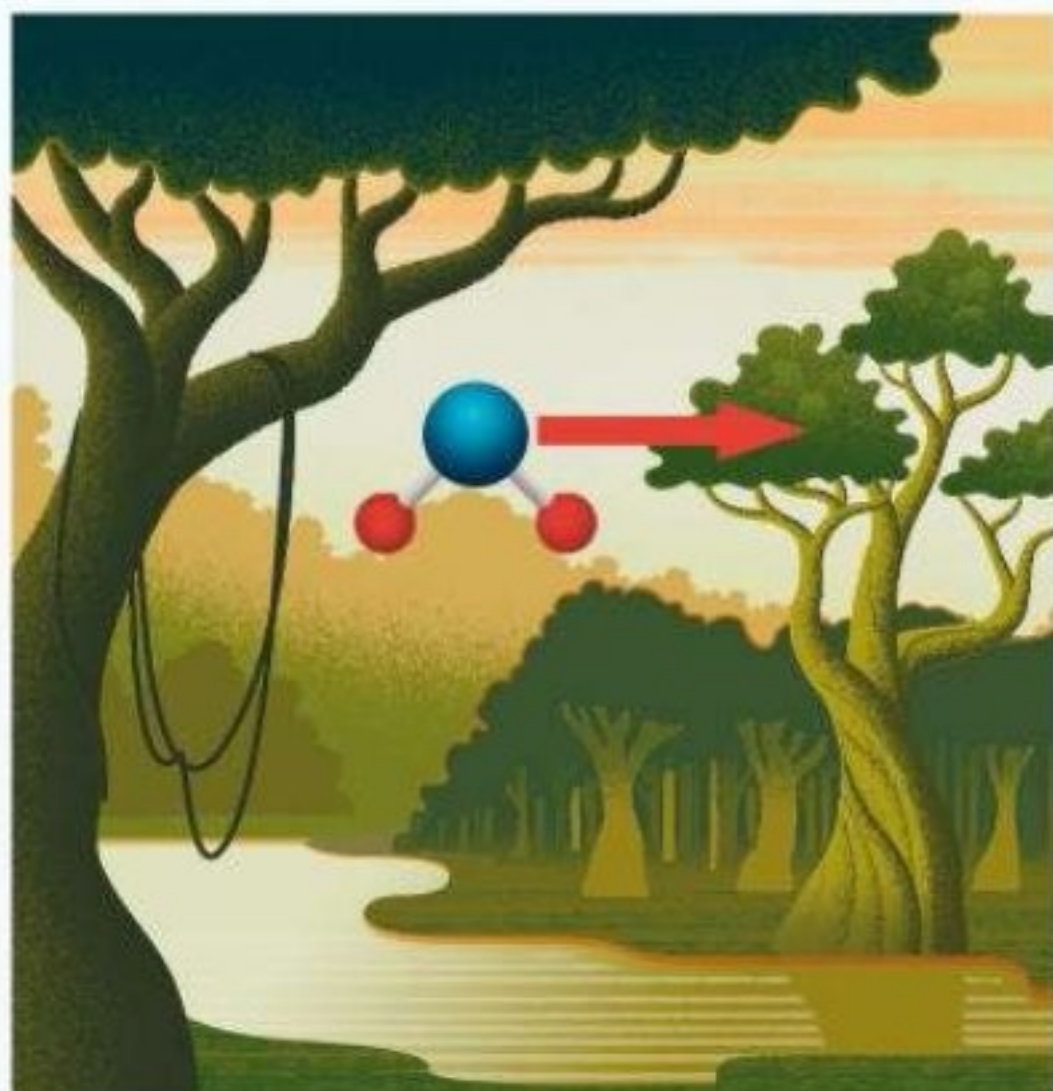
A typical sandwich contains billions upon billions of buzzing electrons. The bonds they form hold together the sugar, carbohydrate, fat and protein we call lunch. The energy in those bonds will eventually power your body, but it can do you no good locked in a sandwich. Luckily, electrons have you covered.

Our electron's journey begins with a bite. Attached to a starch molecule, it is pushed from your mouth to your stomach and then small intestine. Its starchy home is torn asunder by enzymes from the pancreas, and now our intrepid electron is adrift on a molecule of glucose.

A MOSASAURUS BREATHED INTO YOUR STOVE

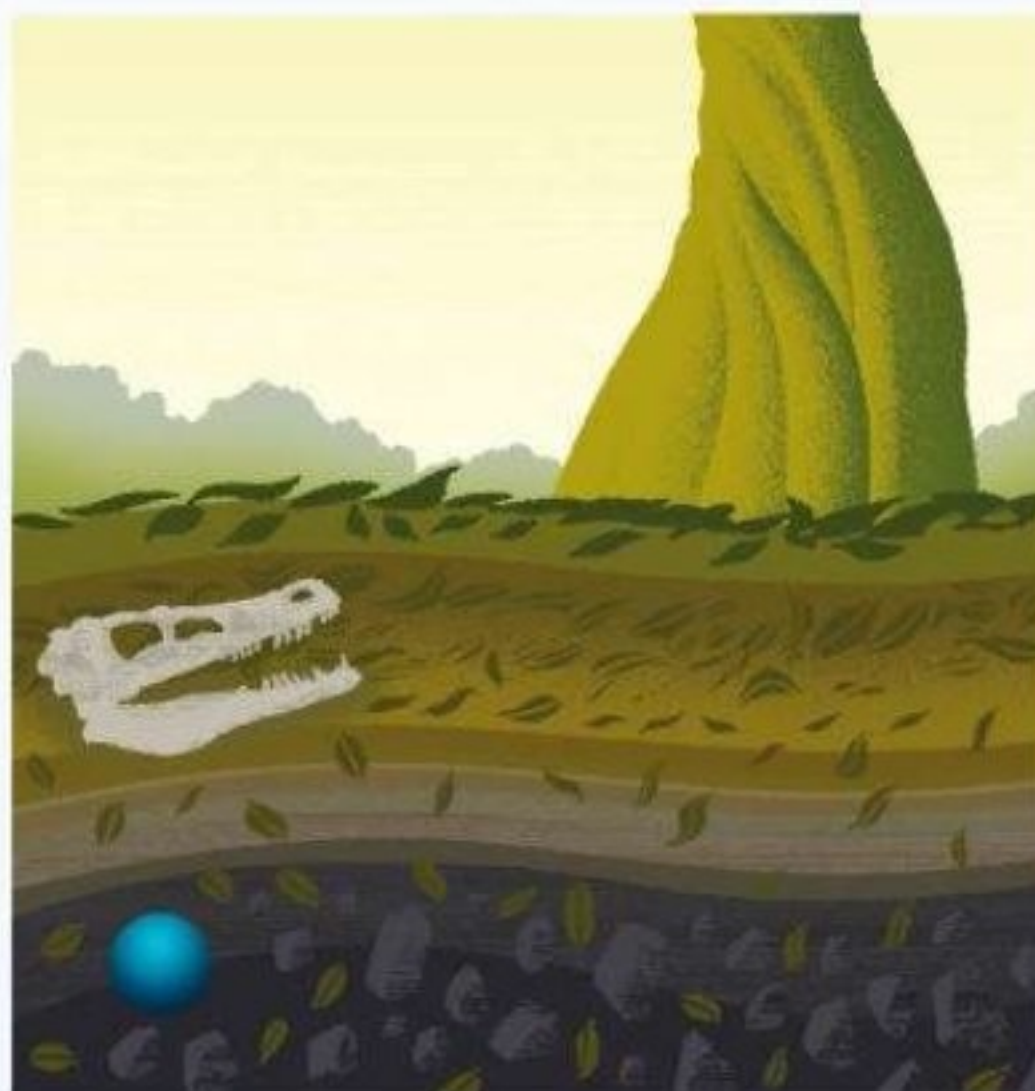
Sixty-six million years ago, a vast shallow sea covers swathes of North America - the Western Interior Seaway. A carbon dioxide molecule is expired into the tropical waters by an 18-metre-long aquatic mosasaurus. It embarks on a journey around the world, flitting between air and ocean, until...

TRAVELLER Carbon atom
ORIGIN A mosasaurus's breath
DESTINATION A coal-fired power plant
DURATION 65 million years



66 mya

Geological forces lift the bottom of the Western Interior Seaway and the sea is replaced by subtropical lakes and swamps. Having travelled around the world, our carbon dioxide returns to North America and is absorbed by a swamp tree. The tree dies, locking the carbon atom inside.



60 mya

Layers of decaying plants and river sludge pile up on the tree's remains. Rising temperatures and pressures crush them into a hard, dark rock: coal.



35 mya

Millennia pass slowly. Far above our carbon, the region begins to dry out. More and more sediment piles on top of the coal, burying it thousands of metres below the surface.

It crosses into the bloodstream, passing briefly through the liver, to join the rush of cells, chemicals and plasma that complete a circuit around the body roughly every minute. Before too long it finds its way into a muscle cell.

The interior of a cell is far from safe. The electron's glucose raft is quickly cut into pieces by a 10-step chemical disassembly line. Hanging on to one of the pieces, our electron is now headed for the cell's power plant: the mitochondrion. This is where the electron's energy truly comes into its own. Inside, it will enter the final stage of its journey: a series of reactions known as the

electron transport chain.

Like a boulder perched at the top of a hill, with a bit of a nudge, the electron tumbles from higher energy states to lower, releasing energy along the way. Enzymes manage the fall, stair-stepping the electron to ever-lower states.

Energy released at each step is used to drive a pump. Protons are pushed, one by one, across a membrane in the mitochondrion and pile up on the far side. Like fans desperate to get inside a stadium, the protons have a single drive - to get back through the membrane. As they push through molecular turnstiles, the energy they release

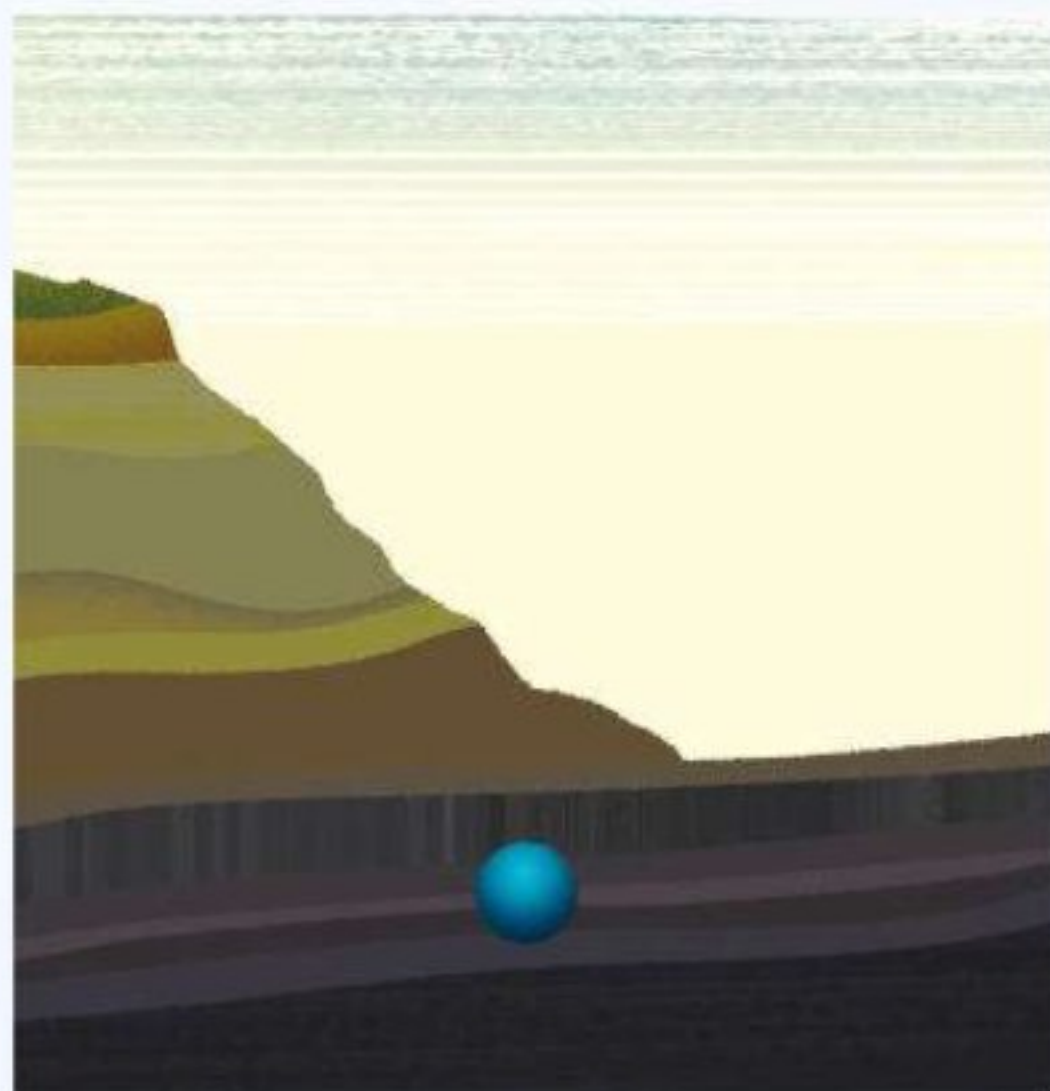
glues a phosphate to an ADP molecule: adenosine diphosphate is turned into adenosine triphosphate. You may have heard of it as ATP. This is the cell's ultimate source of energy.

By the time the electron has bumped its way down to the end of

"Like a boulder perched on top of a hill, with a nudge the electron tumbles, releasing energy as it goes"

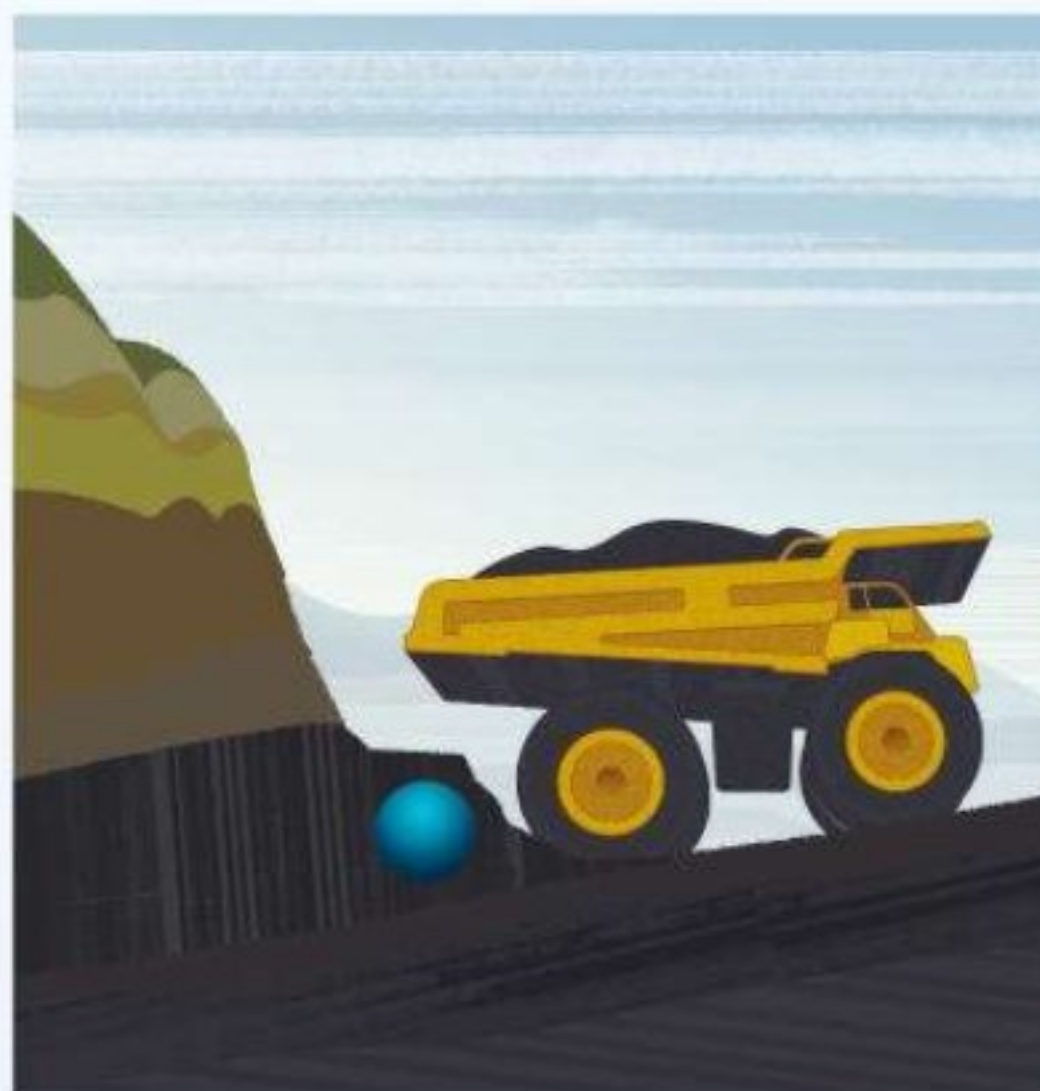
the chain, some 32 ATP molecules have been made. Drained, our electron joins forces with a leftover proton, and two of these hitch themselves to an oxygen to form water. Flushed out of the cell, the water molecule makes its way to the lungs and moistens your breath.

But the electron's energy lives on, in the form of ATP. When, a few hours after lunch, you stub your toe, it helps activate a muscle cell contracting the diaphragm. This expels carbon dioxide and our electron's water molecule out of your lungs. The molecule shoots past your voicebox and out into the world as a cry of pain. MacGregor Campbell



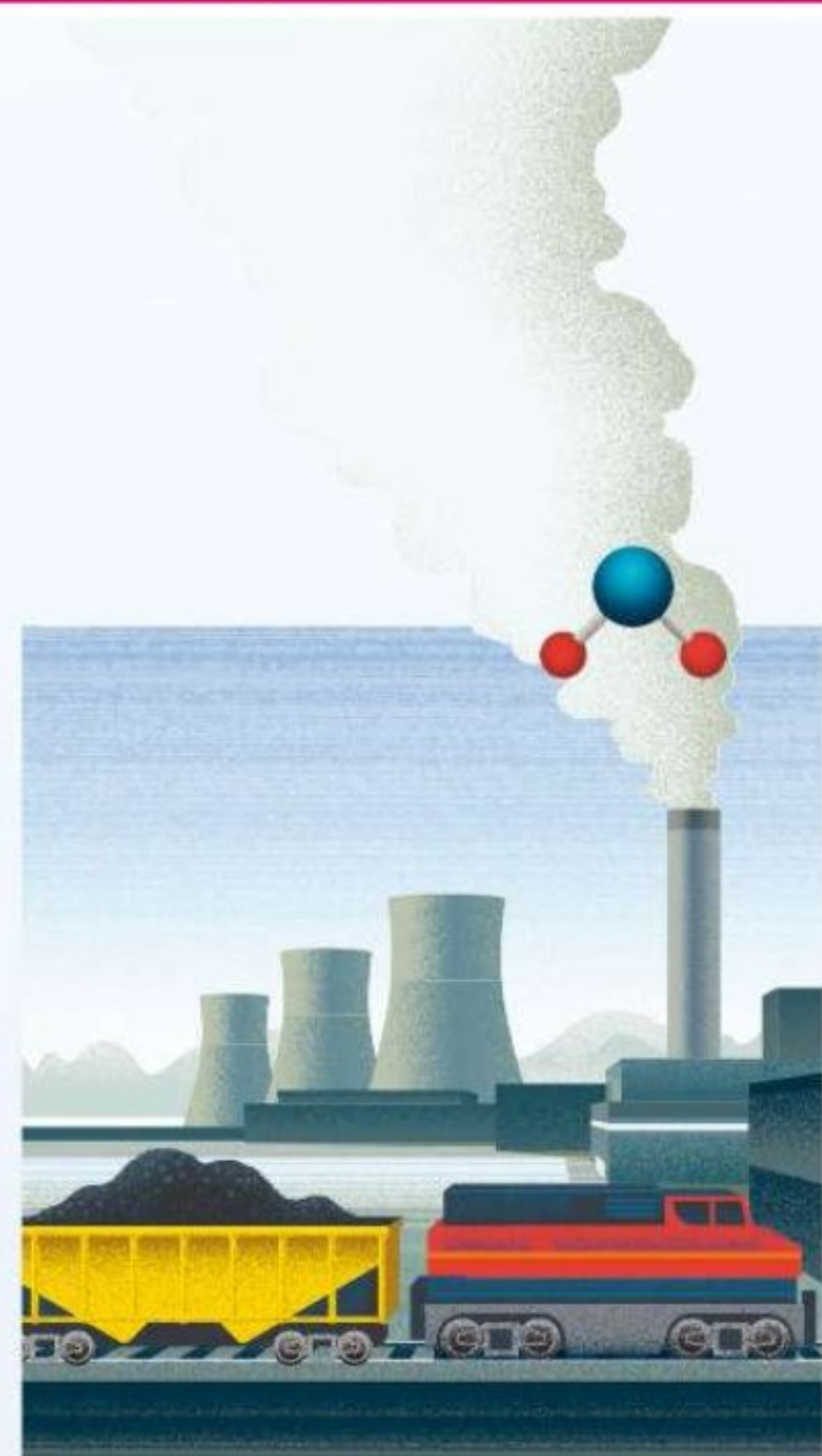
10 mya

Tectonic forces shift and the crust begins to rise. The pressure lessens. Rivers flowing from the majestic Rockies slowly erode the rock above. Our atom is part of what will come to be one of the largest coal seams in the world: the Powder River Basin, stretching across Montana and Wyoming.



1970s

The ground trembles as huge machines tear out tonne after tonne of coal. Our carbon sees the light of day for the first time in 66 million years, and is headed for an entirely different, less peaceful destination.



In a furnace, millions of years of slow formation are reversed in an instant. The energy released by burning the coal briefly powers someone's stove. The fire binds the carbon to oxygen atoms. As carbon dioxide again, it escapes through the flue and into the atmosphere with countless others like it. Many more millions of years will pass before it returns to its deep-earth hideaway. **Catherine Brahic**

TO THE DEPTHS OF THE EARTH AND BACK AGAIN

TRAVELLER A gem as old as the hills
ORIGIN Earth's innards
DESTINATION Asia
DURATION 4 billion years

The zircon crystal comes into being deep inside a young Earth that is covered in ocean and pockmarked by volcanoes spewing white-hot lava. Hundreds of kilometres down, zirconium ions drift in magma droplets through the slowly creeping molten rock. A quirk of mantle currents gathers them beneath a new continent. The magma cools as it rises.

Crystals begin to grow, countless atoms slotting into place in perfectly regular mineral lattices. The zirconium ions form their own crystal, and theirs is quite special: a clear, millimetre-sized structure so hard that it will last for all of eternity – at least as far as Earth is concerned. It is a haven, too, for uranium atoms. As soon as they are encased in the crystal, they begin to decay into lead, starting an atomic clock that will tick for billions of years. Together the gem and its clock will travel the world.

There is no time for rest. The magma is stirring, rising towards a volcanic vent. The zircon flies out of the crust in a luminous whirlwind of hot gas and rock and is dumped in a thick layer of volcanic ash. Later, more ash layers pile above it, and eventually the volcano goes extinct.

Over millions of years, wind and rain slowly exhume the crystal and leave it exposed on a lifeless grey wasteland of rock

and rubble, under an atmosphere of carbon dioxide and methane. It is a dangerous place. Meteorites pound the planet and the thump of one landing nearby rearranges part of the zircon lattice.

A few thousand years pass. Storms slowly inch the crystal across the landscape until finally it tumbles into a river and is dragged out to sea. It's moving much faster now, pushed by currents across the sea floor. The long journey smooths its edges. Sand starts to pile on top of it, and for the second time it ends up deep inside Earth's crust.

When it returns to the surface over a billion years later, pushed up by tectonic forces, the lands and oceans have transformed. Some of the cells that float in the oceans have evolved to harness energy from the sun and are pumping oxygen into the air, which rusts any unstable minerals on the continents. The bare landscape around the zircon is now a pattern of browns and reds.

The crystal is washed into the sea once more, briefly trapped in a slimy mat of microbes, then buried for a third time. For 2 billion years, the tectonic plate it is trapped inside drifts across the globe, crosses the equator, then is crumpled as continents collide. The zircon is sheared and cracked. It holds together – just. Part of its atomic clock is reset by migrations of uranium and lead; more scars that will one day tell the tale of its extraordinary voyage. As mountains rise above, the rocks around it begin to melt. New zirconium ions in the magma cover the ancient gem in a fresh crystal coat with its own atomic clock.

Erupted to the surface for a third time, the battle-scarred and healed zircon lies on a humid, tropical landscape. The skies are alive with birds and in a nearby forest a new animal cry has joined the chorus: the first primate! In a flash of monsoon rains, the crystal is washed into a new river, a new sea and is buried again.

The next time it sees the light of day, 65 million years later, circumstances are very different. A hammer and chisel pound at its

"The tiny crystal is so hard that it will last until the end of the Earth"

rocky bed and the crystal faces its fiercest test. Collected by a human, it is cut on a diamond wheel, probed by an ion beam. The human reads the dates on its atomic clocks, deciphers its long history from its many scars – and, content with the knowledge, throws it away.

Diminished but still resilient, the zircon travels on towards the sea again, and another underground sojourn. Who would bet against it surviving to the end of the Earth? Jan Zalasiewicz is the author of *The Planet in a Pebble* (OUP, 2012)

A DISTANT GALAXY TWEAKS YOUR DNA

TRAVELLER A cosmic ray
ORIGIN A galaxy far, far away
DESTINATION Our atmosphere
DURATION Billions of years, or weeks

ts nursery is the heart of a supergiant star about to explode into a radiant supernova. At a temperature of about 100 million kelvin, atomic nuclei collide and fuse, adding still more heat to the furnace. Just there on the outer edge of the core is our traveller, a product of that fusion: a nucleus of iron.

The star's core has been growing for a few hundred thousand years. Eventually it gets too big to hold itself together and suddenly collapses, generating a supernova blast of radiation that shreds the entire star. Caught in the explosion, the iron picks up speed, is bounced around by a combination of shock waves and turbulent electromagnetic fields, gains more and more energy as it goes, until finally it breaks out of the fireball and flies free.

This is a gentle beginning. Our iron speeds through space, leaving behind it the dead star's glowing nebula. It is headed for the centre of the galaxy, where a monster awaits: a supermassive black hole, a billion times the mass of our sun. Swept up by a stream of gas, the nucleus is dragged perilously close to the point of no return, where it would be inevitably pulled through the black hole's event horizon to who-knows-what beyond. But at the eleventh hour it is caught by the intense magnetic tornado that circles the black hole, catapulted into a jet of plasma, and squirted out at 90 per cent of the speed of light.

The shock waves in this jet are even more extreme than the ones of the supernova fireball, turning the whole thing into a gigantic, tumultuous particle accelerator. High-energy



charged particles bounce off tangled magnetic fields, gaining energy as they are batted around. A few are accelerated to colossal energies.

By the time our iron nucleus leaves this maelstrom, it has an energy of about 8 joules, millions of times greater than anything Earth's Large Hadron Collider can produce. Now at about 99.9999999999999999 per cent of the speed of light, it is flung out of its native galaxy into the emptiness of intergalactic space.

As the iron nucleus wanders between galaxies, pulled this way and that by magnetic fields, its view of the universe is a strange one. At this ludicrous speed, the effects of relativity compress faint starlight from all directions into a single point dead ahead. Relativity also does strange things to time. While the nucleus is travelling, the universe around it ages by 200 million years. In another distant galaxy, Earth's sun completes one lazy orbit of the Milky Way, dinosaurs proliferate, continents split and rejoin. But to the speeding iron nucleus, the whole trip takes about 10 weeks.

On the last day of its intergalactic holiday, our traveller finally approaches the Milky Way's messy spiral. It heads towards a type G2 dwarf star, and a planet where the

dinosaurs are now long dead.

According to on-board time, the iron nucleus passes Pluto just 16 microseconds before it reaches Earth. When it arrives here, we call it an ultra-high-energy cosmic ray.

The wispy gases of our upper atmosphere present a barrier far more challenging than anything it has encountered so far. The iron nucleus hits a nucleus of nitrogen, and the extreme energy of the collision not only obliterates both nuclei, but creates a blast of pions and muons and other subatomic particles, each with enough energy to do the same again to another nucleus, generating a shower of ionising radiation that cascades down through the atmosphere.

Some of these particles will hit an airliner, slightly increasing the radiation dose of passengers and crew. Some may help to trigger the formation of water droplets in a cloud – perhaps even help spark a lightning bolt. Some will find their way into living cells, and one will tweak an animal's genes, spurring on the slow march of evolution. But it is very likely that nobody will even notice as the atmosphere scatters the ashes of an exceptional traveller that once flirted with a giant black hole in the faraway Virgo Cluster. Stephen Battersby

A TWINKLE IN YOUR EYE

TRAVELLER Starlight

ORIGIN Cygnus constellation

DESTINATION Your eye

DURATION 1500 years,
or no time at all

In the outer reaches of a star, a photon is born. It is descended from an ancient family, founded tens of thousands of years ago by a nuclear reaction in Deneb's core. Its ancestors bounced off electrons, were absorbed by ions and gradually spawned offspring of lower and lower energy as they meandered outwards from the core.

This photon is lucky: it is created in the star's photosphere, the thin outer layer from which light can escape into space. It is destined to take a longer journey.

Or from the quantum point of view, infinitely many journeys. The path of a photon between its creation and destruction is not precisely defined. Instead, the particle behaves as though it takes all possible paths,

"This infinity of voyages ends in your eye when you look up at the night sky"

with varying degrees of probability. Our photon's wavefunction, describing that probability, spreads out through all of space – but is densest by far along a fairly straight line between Deneb and Earth.

This infinity of voyages ends at the back of your eye when you look up at the clear night sky. The photon hits a blue-sensitive cell in your retina. Its last act is to trigger a nerve that helps you see a bright blue-white point in the constellation of Cygnus – and then it's gone.

By Earthly reckoning the trip has taken between 1500 and 3000 years (the distance from Deneb to Earth is not yet known precisely). It may have begun while Franks and Visigoths were at war, or back when some Phoenician scribe was developing the first alphabet.

But to the photon it lasts no time at all. If you move at the speed of light, time and space shrink to nothing. From this point of view the journey's beginning and end are the same point... in which case you might say that your eye is touching the fiery surface of Deneb, a seething shell of plasma with a temperature of more than 8000 kelvin. Stephen Battersby ■

When axions strike

A 40-year-old idea is on course to knock down three of the biggest mysteries in physics at once. **Jon Cartwright** sizes it up

TO MOST of us the mass of an eyelash seems like just about nothing. But to a Higgs boson – the particle believed to endow all others with their mass – it might as well weigh a tonne. The mass of the Higgs has a bearing on all the other particles that make up reality, and if it were as large as an eyelash the world would look very different. The electrons buzzing inside your computer's circuits would be as weighty as the dust coating the top of it. If the dust bulked up on the same scale, each speck would have roughly the mass of a well-fed elephant.

A strange world indeed. Yet believe the standard model, our best theory of particle physics, and this is just the sort of situation we should expect to find ourselves in. According to this idea, the Higgs should be roughly the mass of an eyelash. This is so big that it would produce fundamental particles almost so massive and dense that they would create a microscopic black hole every time they collided.

Yet none of the fundamental particles – electrons, quarks, neutrinos and so on – are anywhere near the mass they ought to be. They're all much smaller: 100 quadrillion times smaller.

Why the clustering at the bottom? This "hierarchy problem" has haunted physicists for decades, and there's never been an easy answer. The front runner, a theory known as supersymmetry, has fallen from grace now that the Large Hadron Collider (LHC), located near Geneva, Switzerland, has searched the

most obvious avenues for evidence and failed to find it.

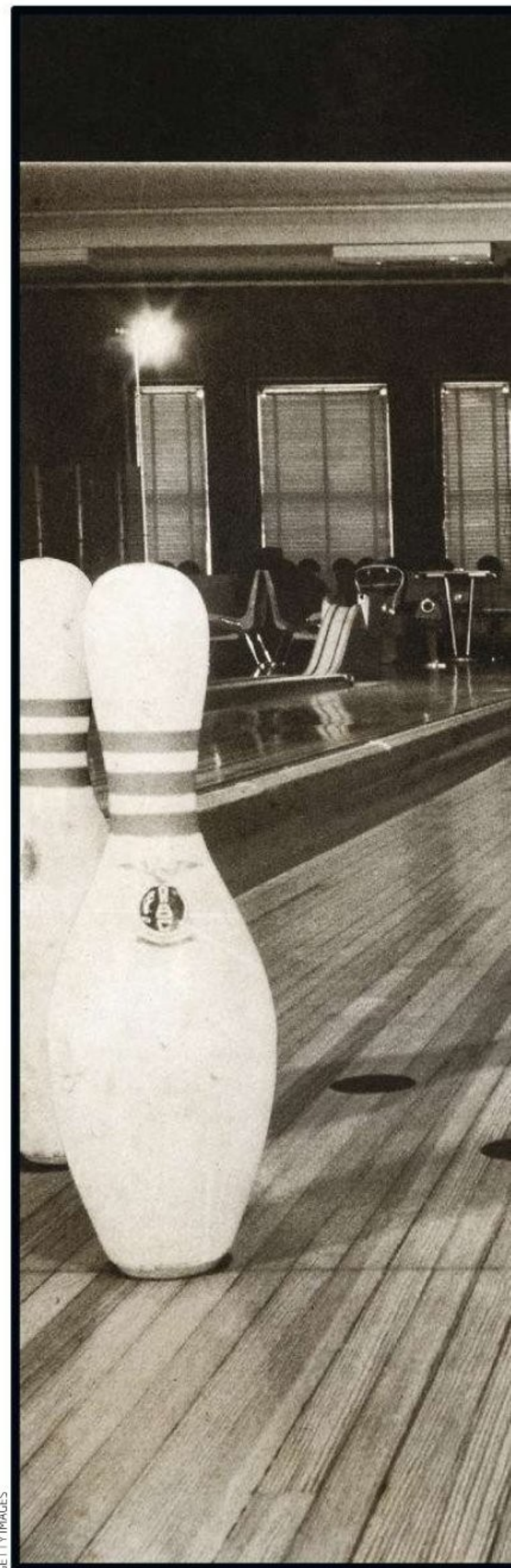
We're desperate for a way to explain this puzzle. But perhaps the answer has been under our noses all along. According to a trio of physicists with a grand idea, a single particle known as the axion, a plaything of theorists since the 1970s, makes the problem disappear in a flash – and fixes a couple of other mysteries on the side.

People had started to give up on the hierarchy problem as being solvable without resorting to far-fetched explanations, says David Kaplan at Johns Hopkins University in Baltimore, Maryland. "What's shocking some is that the axion, a very old idea, is all of a sudden playing a role."

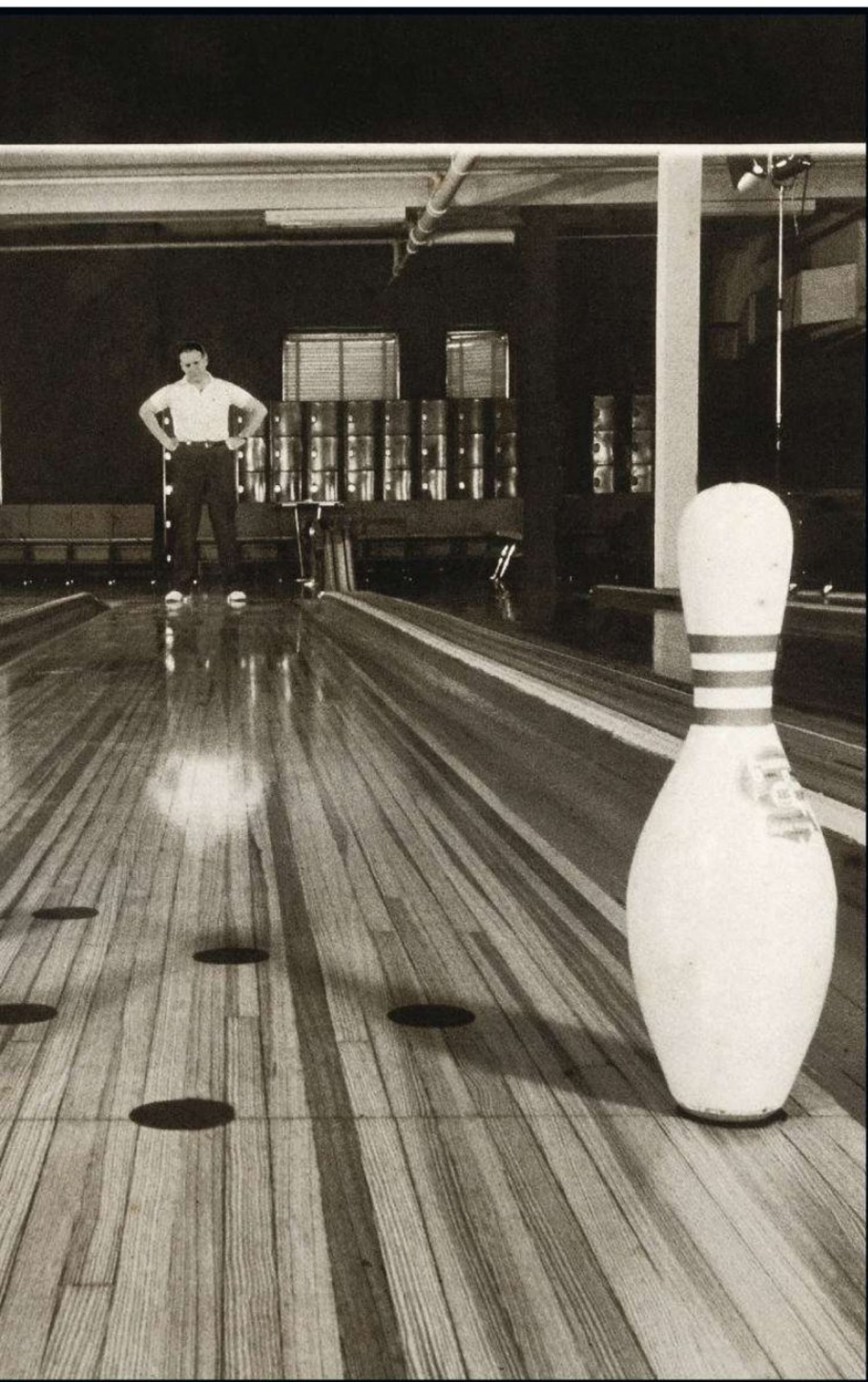
Until recently, mass itself was an ill-defined concept. Everyone intuitively understands it as the thing that gravity acts on to bring objects down to Earth, and that makes it harder to accelerate a truck than a bicycle. Quite how mass does what it does, though, no one could say for sure.

That changed in 2012, when researchers at the LHC found what appeared to be the long-sought Higgs boson – thought to be the manifestation of an invisible Higgs field that permeates space. It is the gloopy, molasses-like quality of this field that provides the resistance to motion that is the hallmark of mass.

The discovery of the Higgs was a terrific victory for science, but it brought the hierarchy problem back into full view. If all the other particles are much, much lighter than



GETTY IMAGES



“The axion could explain why everything is too light - plus two other mysteries on the side”

we'd expect, then the Higgs must have something to do with it.

To grapple with that idea, we need to deal with a strange-sounding concept: the mass of the Higgs. How can the mass-giving particle have a mass of its own? It turns out that under the rules of quantum mechanics, it can temporarily shape-shift into all sorts of other particles, acquiring their masses in the process. Add up the effect of these quantum fluctuations and we get a value for the Higgs mass verging on the upper limit – that of the eyelash. Expressed in the normal units of particle physics, that's about 10^{19} gigaelectronvolts (GeV).

A massive fudge

So when researchers at the LHC found the Higgs mass roughly where they thought it would be, at a paltry 125 GeV, it confirmed their worst fears: there's something massive missing from our understanding of the Higgs.

A blunt resolution to this huge discrepancy is to assume that it has some sort of inherent mass, independent of all the quantum fluctuations, and that this is also very large. When physicists delved into the maths, they found a way to make the two masses just about cancel out, with whatever remains being the mass we actually measure.

In dark times a physicist might contemplate such a fudge. But what are the chances of two unrelated, multizillion figures cancelling almost perfectly? “In the case of the Higgs, ➤

something funny is going on,” says Kaplan.

Looked at this way, the hierarchy problem is a coincidence of cosmic proportions. It’s a bit like driving a golf ball towards the green, only to see it deflect off a tree into a bunker, bounce into a lake and then rebound to land within inches of the club you hit it with. And the improbability is not just limited to the boson. Because the masses of all the fundamental particles scale with the Higgs, the problem affects just about everything.

Theorists loved supersymmetry because it appeared to offer a path out of this mess. The theory posits that every known fundamental particle has a twin – a superparticle, or “sparticle” – that cancels out the contribution of its conventional partner when totting up all the Higgs’s quantum fluctuations. In this way, the mass due to quantum fluctuations drops almost to zero – the small remainder being the mass difference between particles and sparticles. That would leave everything neatly tied up.

There’s just one problem: sparticles should have been lurking just a bit further into unexplored territory than the Higgs, but none have shown up at the LHC. “The Higgs should have been the tip of the iceberg,” says Kaplan.

With supersymmetry looking shaky, many physicists are contemplating a last-ditch explanation. In a sprawling multiverse, runs

PARTICLE HAT-TRICK

If the hypothetical axion particle does exist, it has a shot at solving three of the biggest mysteries in physics at once.

After the hierarchy problem (see main story) there is the strong charge parity problem. Imagine an interaction between two particles, and then imagine what it would look like if you could view its mirror image, with the particles’ charges also swapped. By intuition, you would expect the result to be physically indistinguishable (known as charge parity symmetry), but many processes we observe in nature aren’t like this. Those governed by the fundamental mechanism known as the strong force do however always appear to be, for reasons unknown. If the axion exists, its field would act like a strict drill sergeant and keep the symmetry violations in check.

Axions are also perfect candidates for dark matter, the invisible stuff that accounts for 80 per cent of the mass of the universe. They are uncharged and only interact very weakly with other matter, so they are very hard to observe directly. It’s worth trying though. These particles pay triple.

the idea, the Higgs mass might take on any number of values and we just happen to be living in one of few regions in the universe where it is very small. The trouble with this idea is that it’s nigh on impossible to test.

“What we’re putting forward is a third way,” says Kaplan. It all started in 2014, when Kaplan’s colleagues, Surjeet Rajendran at the University of California, Berkeley, and Peter Graham at Stanford University, devised a new type of experiment to detect an axion.

They’re rather interesting things, axions. If they exist, they are light, electrically neutral particles that generate their own unique force. They were first proposed more than 40 years ago to explain a vexing issue known as the strong charge parity problem. They are also prime candidates for dark matter, so if they can add the hierarchy problem to their laundry list it would be an impressive feat for such a small – albeit hypothetical – object (see “Particle hat-trick”, left).

But none of the axion detectors so far devised has seen anything. Rajendran and Graham had a new design up their sleeves and were about to apply for funding to build it when a team claimed to have detected long-sought evidence of a period of rapid inflation early in the universe, using the BICEP telescope near the South Pole. That looked to rule out the existence of axions.

Rajendran wasn’t so sure, and after some head-scratching, he figured out a way to square the BICEP result with the existence of axions. It required the axion to have had a large mass in the early universe, which then petered out. But this didn’t convince anyone to fund their detector. And to rub salt in the wound, a raft of reports soon appeared saying the BICEP claim wasn’t valid anyway.

But never mind: the episode had got Rajendran thinking about much broader issues than just axions. If that particle’s mass could decrease over time, he thought, could that apply to other particles such as the Higgs boson too?

Mass mystery

Rajendran and Graham got in touch with Kaplan, and together they began applying the diminishing-mass idea to the hierarchy problem. What if, they wondered, the masses of the axion and Higgs were somehow linked, like two wheels on an axle? That way both particles could start off in the early universe at the gigantic mass predicted by the standard model, and then slowly roll downhill.

On its own, the idea didn’t solve anything.

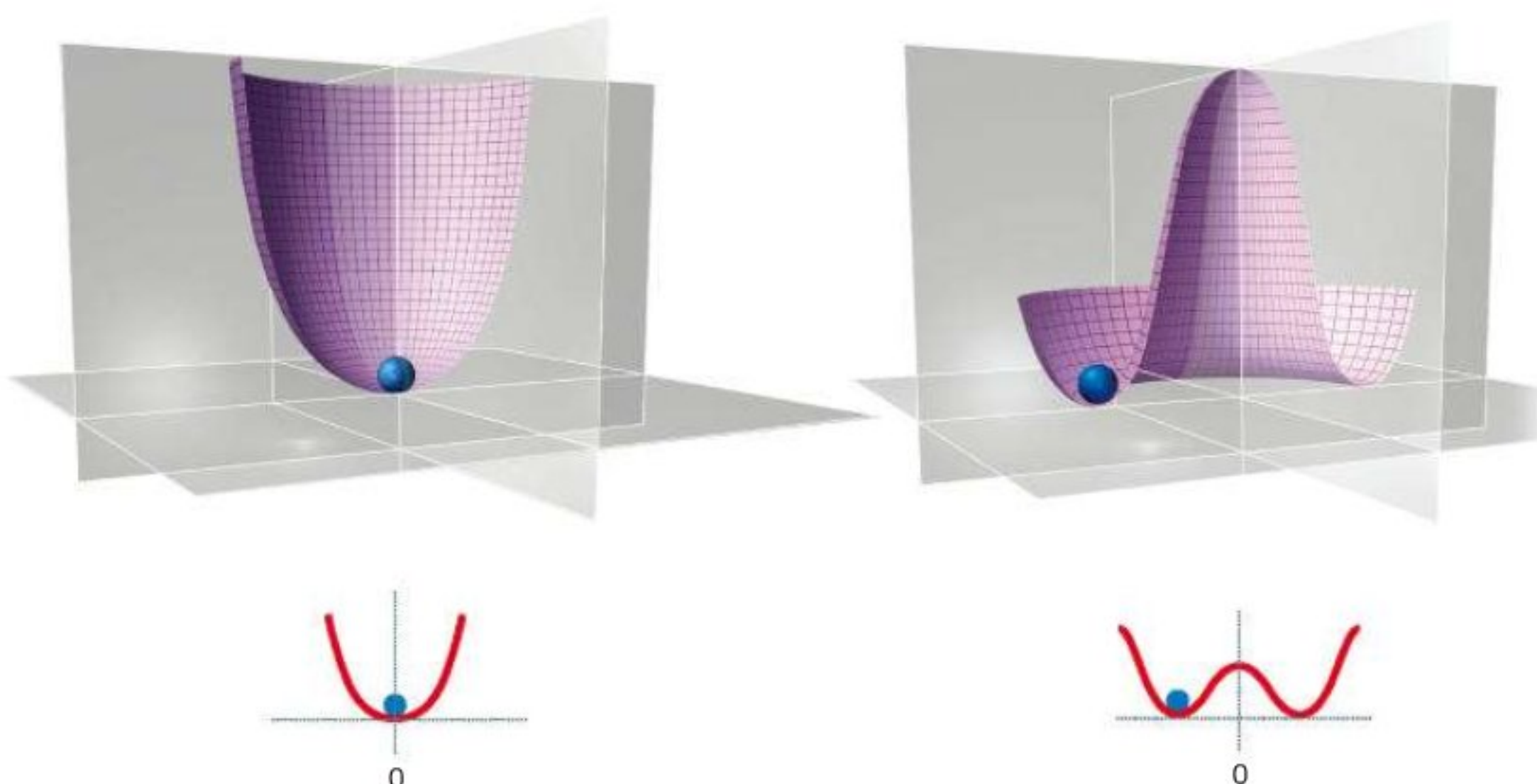
Playing with hats

Early universe

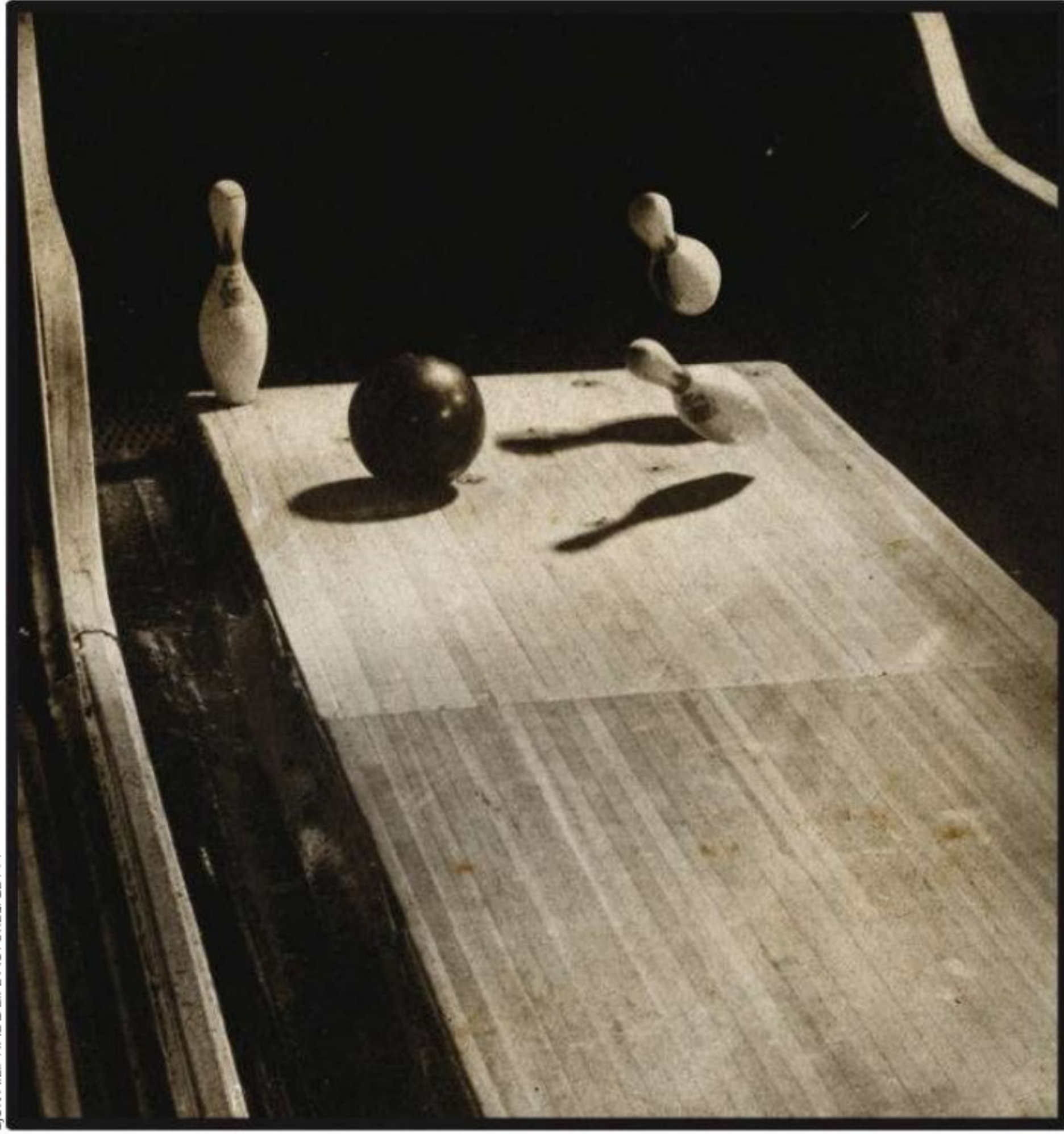
In the early universe, the Higgs field potential was like an inverted bowler hat. That meant that the Higgs boson always fell to the centre, keeping it at 0 and so effectively switched “off”

Today

But today, the Higgs field potential can be represented by a Mexican hat shape, which pushes the boson away from centre into an “on” position, where it can give the feeling of mass everywhere



"Before this theory, people had almost given up trying to solve the hierarchy problem"



GION MILI/TIME & LIFE PICTURES/GETTY

Why would the Higgs mass grind to a halt at 125 GeV, rather than keep falling? Gradually, Graham, Kaplan and Rajendran arrived at the idea that the mass-giving nature of the Higgs itself may have switched on only when its mass dipped below a certain value. This could have locked everything in place, but it was tortuous to convert it into solid theory. "It took us six months to figure out something that actually works," says Kaplan.

Understanding this mechanism requires a little detour into what makes the Higgs so special in the first place. The Higgs field is just like the electromagnetic field, through which we experience magnetism, light and solid objects – but with an important difference. Whereas electromagnetism is absent, or "off", unless there is something nearby to generate it – a magnet or lamp, say – the Higgs field is on everywhere.

Physicists often explain this characteristic using headgear. If you were to turn a bowler hat upside down and drop in a marble, it would eventually come to rest at the centre – corresponding to a value of zero, or "off". But now do the same with a Mexican hat, and keep

it the right way up. Faced with that tall crown, the marble cannot remain at the hat's central axis. Instead, it falls down to the brim, representing an "on" state (see "Playing with hats", [page 38](#)).

Today the Higgs field is like a Mexican hat because mass is always on. Looking at their equations, however, Graham, Kaplan and Rajendran realised it needn't always have been so. In its early supermassive state, the Higgs would have been an inverted bowler hat, its field turned off. By tweaking the link between the axion and the Higgs, they could design it so that the Mexican hat – and the mass-giving powers – only appeared when the Higgs's own mass was close to zero.

Once the Higgs was in that state, it stayed that way thanks to a self-reinforcing loop. This kicked in because the fundamental particles gaining mass from the Higgs include quarks, which are glued together inside atoms by the strong force. And it turns out that axions interact with the strong field themselves, so the quarks' sudden mass would have put a cap on the axion. It was just what the trio had been searching for. "Bingo! We solve the hierarchy

problem," says Rajendran.

Back in the 1970s, the axion was named after a then-popular detergent thanks to its ability to clean up the strong charge parity problem. But in their paper proposing the idea, published in April (arxiv.org/abs/1504.07551), the team suggested tweaking the axion's name to "relaxion", given how it causes the mass of the Higgs to relax nicely down to its observed value.

"The relaxion idea is quite fascinating, and it has generated a lot of heated discussion," says particle physicist Jesse Thaler at the Massachusetts Institute of Technology.

Cosmically relaxed

Some of this heat surrounds the mechanism governing the axion's link to the Higgs – the fist that changes the shape of the hat, if you will. Graham, Kaplan and Rajendran admit they have invented this mechanism and jiggled its strength to suit their theory. It sounds slippery, but it could be a worthwhile tactic. At the very least, it may give physicists a thread to tug at, making the hierarchy problem easier to start tackling compared with the previous state of play, where there was no obvious starting place.

Not everyone sees it like that though. "It could be that this is easier, but it's not guaranteed," says theorist Jörg Jäkel at Heidelberg University in Germany.

The relaxion idea does have one advantage over other answers to the hierarchy problem. There are detectors out there hunting for axions now, such as the recently revamped axion dark matter experiment at the University of Washington, Seattle.

But rather than waiting for the detectors to ping, Graham, Kaplan and Rajendran are working on an audacious new idea. Can relaxion theory solve a fourth big mystery?

The "cosmological constant" is the number physicists plug into equations to represent the energy pushing space apart, inflating the universe. But although the rules of quantum theory say this number must be gargantuan, an arbitrarily small number is famously needed for the expansion to tally with observations.

Sound familiar? The trio are wondering if maybe, just maybe, a similar sort of relaxation argument might unlock the problem. "It's a rough one, but we're having a go at it," says Kaplan. "We've been buoyed by the fact that we've been able to hit the hierarchy problem so successfully, in such a dramatic way." ■

Jon Cartwright is a freelance journalist based in Bristol, UK

Roots of brutality

Is evil a disease? **Laura Spinney** reports on how this contentious idea might help avert massacres and radicalisation

PADOLO PELLEGRIN/MAGNUM PHOTOS



The Srebrenica massacre was the worst in Europe since World War II

WHY would an apparently normal young adult drop out of college and turn up some time later in a video performing a cold-blooded execution in the name of jihad? It's a conundrum we have been forced to ponder ever since a group calling itself ISIS declared war on infidels. But 70 years ago we were asking something similar of guards in Nazi concentration camps – and, sadly, there have been plenty of opportunities to ponder the matter in between.

What turns an ordinary person into a killer? The idea that a civilised human being might be capable of barbaric acts is so alien that we often blame our animal instincts – the older, “primitive” areas of the brain taking over and subverting their more rational counterparts. But fresh thinking turns this long-standing explanation on its head. It suggests that people perform brutal acts because the “higher”, more evolved, brain overreaches. The set of brain changes involved has been dubbed Syndrome E – with E standing for evil.

In a world where ideological killings are rife, new insights into this problem are sorely needed. But reframing evil as a disease is controversial. Some believe it could provide justification for heinous acts or hand extreme organisations a recipe for radicalising more young people. Others argue that it denies the reality that we all have the potential for evil within us. Proponents, however, say that if evil really is a pathology, then society ought to try to diagnose susceptible individuals and reduce contagion. And if we can do that, perhaps we can put radicalisation into reverse, too.

Following the second world war, the behaviour of guards in Nazi concentration camps became the subject of study, with some researchers seeing them as willing, ideologically driven executioners, others as mindlessly obeying orders. The debate was reignited in the mid-1990s in the wake of the Rwandan genocide and the Srebrenica massacre in Bosnia. In 1996, *The Lancet* carried an editorial pointing out that no one was addressing evil from a biological point of view. Neurosurgeon Itzhak Fried, at the University of California, Los Angeles, decided to rise to the challenge.

In a paper published in 1997, he argued that the transformation of non-violent individuals into repetitive killers is characterised by a set of symptoms that suggests a common condition, which he called Syndrome E (see “Seven symptoms of evil”, [page 42](#)). He suggested that this is the result of “cognitive fracture”, which occurs when a higher brain region, the prefrontal cortex (PFC) – involved in rational thought and decision-making – stops paying attention to signals from more primitive ➤

brain regions and goes into overdrive.

The idea captured people's imaginations, says Fried, because it suggested that you could start to define and describe this basic flaw in the human condition. "Just as a constellation of symptoms such as fever and a cough may signify pneumonia, defining the constellation of symptoms that signify this syndrome may mean that you could recognise it in the early stages." But it was a theory in search of evidence. Neuroscience has come a long way since then, so Fried organised a conference in Paris earlier this year to revisit the concept.

At the most fundamental level, understanding why people kill is about understanding decision-making, and neuroscientists at the conference homed in on this. Fried's theory starts with the assumption that people normally have a natural aversion to harming others. If he is correct, the higher brain overrides this instinct in people with Syndrome E. How might that occur?

Etienne Koechlin at the École Normale Supérieure in Paris was able to throw some

"The set of brain changes has been dubbed Syndrome E - with E standing for evil"

empirical light on the matter by looking at people obeying rules that conflict with their own preferences. He put volunteers inside a brain scanner and let them choose between two simple tasks, guided by their past experience of which would be the more financially rewarding (paying 6 euros versus 4). After a while he randomly inserted rule-based trials: now there was a colour code indicating which of the two tasks to choose, and volunteers were told that if they disobeyed they would get no money.

Not surprisingly, they followed the rule, even when it meant that choosing the task they had learned would earn them a lower pay-off in the free-choice trials. But something unexpected happened. Although rule-following should have led to a simpler decision, they took longer over it, as if conflicted. In the brain scans, both the lateral and the medial regions of the PFC lit up. The former is known to be sensitive to rules; the latter receives information from the limbic system, an ancient part of the brain that processes emotional states, so is sensitive to our innate preferences. In other words, when following the rule, people still considered their personal preference, but activity in the lateral PFC overrode it.

Of course, playing for a few euros is far



SHAHID AZIZ/EPH

removed from choosing to kill fellow humans. However, Koechlin believes his results show that our instinctive values endure even when the game changes. "Rules do not change values, just behaviours," he says. He interprets this as showing that it is normal, not pathological, for the higher brain to override signals coming from the primitive brain. If Fried's idea is correct, this process goes into overdrive in Syndrome E, helping to explain how an ordinary person overcomes their squeamishness to kill. The same neuroscience may underlie famous experiments conducted by the psychologist Stanley Milgram at Yale University in the 1960s, which revealed the extraordinary lengths to which people would go out of obedience to an authority figure – even administering what they thought were lethal electric shocks to strangers.

Fried suggests that people experience a visceral reaction when they kill for the first time, but some rapidly become desensitised. And the primary instinct not to harm may be more easily overcome when people are "just following orders". In unpublished work,

SEVEN SYMPTOMS OF EVIL

The idea that evil is a disease is predicated on the observation that mass killers share some common traits:

- Compulsive repetitive violence
- Obsessive beliefs**
- Rapid desensitisation to violence
- Flat emotional state**
- Separation of violence from everyday activities
- Obedience to an authority**
- Perceiving group members as virtuous

Palestinian children: freedom fighters or potential terrorists?

Patrick Haggard at University College London has used brain scans to show that this is enough to make us feel less responsible for our actions. "There is something about being coerced that produces a different experience of agency," he says, "as if people are subjectively able to distance themselves from this unpleasant event they are causing."

However, what is striking about many accounts of mass killing, both contemporary and historical, is that the perpetrators often choose to kill even when not under orders to do so. In his book *Ordinary Men*, the historian Christopher Browning recounts the case of a Nazi unit called reserve police battalion 101. No member of this unit was forced to kill. A small minority did so eagerly from the start, but they may have had psychopathic or sadistic tendencies. However, the vast majority of those who were reluctant to kill soon underwent a transformation, becoming just as ruthless. Browning calls them "routinised" killers: it was as if, once they had decided to kill, it quickly became a habit.

Habits have long been considered unthinking, semi-automatic behaviours in which the higher brain is not involved. That seems to support the idea that the primitive brain is in control when seemingly normal people become killers. But this interpretation is challenged by new research by neuroscientist Ann Graybiel at the Massachusetts Institute of Technology. She studies people with common psychiatric disorders, such as addiction and depression, that lead them to habitually make bad decisions. In high-risk, high-stakes situations, they tend to downplay the cost with respect to the benefit and accept an unhealthy level of risk. Graybiel's work suggests the higher brain is to blame.

In one set of experiments, her group trained rats to acquire habits – following certain runs through mazes. The researchers then suppressed the activity of neurons in an area of the PFC that blocks signals coming from a primitive part of the brain called the amygdala. The rats immediately changed their running behaviour – the habit had been broken (*PNAS*, vol 109, p 18932). "The old idea that the cognitive brain doesn't have evaluative access to that habitual behaviour, that it's beyond its reach, is false," says Graybiel. "It has moment-to-moment evaluative control." That's exciting, she says, because it suggests a way to treat people with maladaptive habits such as obsessive-compulsive disorder, or even, potentially, Syndrome E.

What made the experiment possible was a technique known as optogenetics, which



ZUMA PRESS/EYEVINE

Guantanamo Bay, Cuba, where detainees are "quarantined"

allows light to regulate the activity of genetically engineered neurons in the rat PFC. That wouldn't be permissible in humans, but cognitive or behavioural therapies, or drugs, could achieve the same effect. Graybiel believes it might even be possible to stop people deciding to kill in the first place by steering them away from the kind of cost-benefit analysis that led them to, say, blow themselves up on a crowded bus. In separate experiments with risk-taking rats, her team found that optogenetically decreasing activity in another part of the limbic system that communicates with the PFC, the striatum, made the rats more risk-averse: "We can just turn a knob and radically alter their behaviour," she says (*Cell*, vol 161, p 1320).

Whether society would condone such interventions is a different matter, as Graybiel acknowledges. If one person's terrorist is another's freedom fighter, then who should define maladaptive behaviour? This point is reinforced by anthropologist Scott Atran of the University of Michigan, who earlier this year addressed the UN Security Council about his research on ideologically motivated violence. "Al-Qaida and ISIS argue that the attacks on Hiroshima and Nagasaki, without regard to civilian casualties, are evil," he says.

Atran opposes the idea of pathologising evil and others share his qualms. For social psychologist Stephen Reicher at the University of St Andrews, UK, the problem with Syndrome E is that it divides the world into them and us. It supposes that only people with flawed minds are capable of evil, when in fact everyone is, given the right (or wrong) context. If we want to make the world a less violent place, he says, we have to consider that context. And that requires us to step back from the individual and look at the group.

The notes that Milgram kept during his

famous experiments are revealing, Reicher says, because they show that people actually displayed the whole gamut of responses, from enthusiastic participation to refusal via anxious indecision. What determined an individual's response was whether they identified more with the experimenter – the authority figure – or the victim. He believes that the key question is how the perpetrators of massacres define themselves – the group they identify with and who, as a non-member, they perceive as a threat.

This makes sense given what we know about group behaviour. Humans evolved as ultra-social animals, relying on group membership for survival. Our tendency to group together is so intense that just glimpsing a flash of colour is enough for us to affiliate with a stranger sporting the same colour. Cognitive neuroscientist Julie Grèzes, also at the École Normale Supérieure, argues that belonging to even such a small and ephemeral group determines how we perceive outsiders. We feel less empathy towards people outside our group, and we can literally dehumanise them.



JOHN VINK/MAGNUM PHOTOS

Khmer Rouge jailer Duch claimed he was just obeying orders

Because we tend to adopt the beliefs and values of any group we identify with, our groups also influence how we behave towards outsiders. "What is truly toxic," says Reicher, "is a construction of in-group and out-group which makes genocide an act of virtue and construes the killers as the most noble among us."

But groups can be a good and civilising force too. In fact, resistance to violence also tends to occur in the form of collectives, as demonstrated by the three young people from the US who foiled a gunman's attempted attack on a French train in August. Solitary types, on the other hand, might be the easiest prey for those espousing violent extremism.

Herein lies the yin and yang of the problem. We should actually encourage group membership, Reicher argues, because it may be the best protection against the unhealthy conviction that we are more virtuous than people outside our group. We should also educate people to be wary of such black-and-white moral distinctions, he says.

Spot the symptoms

So where does that leave us? Both Reicher and Atran believe that future research should focus less on why people decide to perform extreme acts, and more on what draws them to extreme organisations in the first place. Speaking at the UN, Atran argued that young people need a dream. Appeals for moderation will never be attractive to "youth, yearning for adventure, for glory, for significance", he said.

But Fried is encouraged that neuroscience has bolstered the idea of Syndrome E, and still believes we can benefit from thinking in terms of what is going on inside the brain of a killer. What's more, group dynamics might help explain why the PFC is at the root of evil. After all, the recently evolved parts of the brain respond to rules precisely because rules are essential for the smooth functioning of groups. The possibility that this useful response may go into overdrive is perhaps the price we pay.

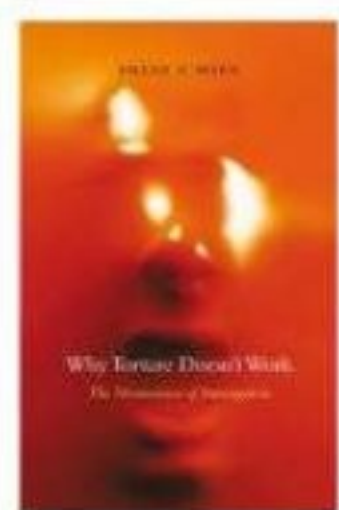
Fried is not a proponent of using drugs to treat Syndrome E. Instead, he thinks we should use our growing neuroscientific knowledge to identify radicalisation early, isolate those affected and help them change. "The signs and symptoms should be made widely known, so that people can spot them," he says. When it comes to prevention, he thinks education is probably the key. And in that, at least, he agrees with his detractors. ■

Laura Spinney is a writer based in Paris, France

Secrets and lies

Torture doesn't work, says science. **Carl Elliott** doubts torturers care

Why Torture Doesn't Work: The neuroscience of interrogation by Shane O'Mara, Harvard University Press, \$29.95/£22.95



"IF YOU torture the data long enough," the saying goes, "it will confess to anything." Although this is a problem for scientists, the

stakes are higher for torturers. If tortured people really will tell you anything, how do you know when they are telling the truth?

Why Torture Doesn't Work has a specific origin, says its author Shane O'Mara, professor of experimental brain research at Trinity College Dublin in Ireland. In 2009, he read an article about the release of the "Torture Memos", legal documents prepared for the US federal authorities on the use of waterboarding, sleep deprivation, binding in stress positions, and other "enhanced interrogation" techniques.

Morality aside, O'Mara wanted to know if there was credible science that showed torture worked. The answer, it turns out, is no. The reality is that "the intelligence obtained through torture is so paltry, the signal-to-noise ratio so low, that proponents of torture are left with an indefensible case". Advocates defend torture with an "ad hoc mixture of anecdote, cherry-picked stories and entirely counterfactual scenarios", he says.

Controlled studies on the effectiveness of torture would

be morally abhorrent. But there is a lot of information on the psychological and physiological effects of severe pain, fear, extreme cold, sleep deprivation, confinement and near-drowning. Some studies, such as those on the effects of sensory deprivation, used healthy volunteers. Others were conducted during the training of combat soldiers.

There is also a small amount of literature on the severe, long-term effects of torture on those who survive it, and work on the efficacy of police-interrogation techniques, which has produced insights into the psychology of false confessions – alarmingly easy to produce.

As O'Mara emphasises, torture does not produce reliable information largely because of the severity with which it impairs the ability to think. Extreme pain, cold, sleep deprivation and fear of torture itself all damage memory, mood and cognition. Torture does not persuade people to make a reasoned decision to cooperate,

but produces panic, dissociation, unconsciousness and long-term neurological damage. It also produces an intense desire to keep talking to prevent further torture.

O'Mara quotes an intelligence officer's story about a 60-year-old torture survivor in Cambodia: "He told his interrogators everything they wanted to know, including the truth. In torture, he confessed

"One survivor confessed to being everything from a hermaphrodite to the King of Cambodia's son"

to being everything from a hermaphrodite, and a CIA spy to a Catholic bishop and the King of Cambodia's son. He was actually just a school teacher whose crime was that he once spoke French."

Interrogators often escalate torture when they think a suspect is withholding information or lying, but there is no good evidence that interrogators are better than the rest of us at detecting lies. In

fact, there is evidence that when people are trained as interrogators, they become more likely to think others are lying to them. This belief can lead to alarming errors, whereby people are tortured because their torturer wrongly believes they are lying. New technologies to detect lies do not work either, says O'Mara.

Why Torture Doesn't Work is a valuable book. O'Mara builds his case like a prosecutor, citing scientific studies and relentlessly poking holes in absurdities and inconsistencies in documents such as the "Torture Memos". Whether science matters to those who defend torture is another matter, as O'Mara knows: their motivation is often punitive, not practical. But once torture is imposed, the consequences, he says, are that it will be "ineffective, pointless, morally appalling, and unpredictable in its outcomes". ■

Carl Elliott is professor at the Center for Bioethics, University of Minnesota



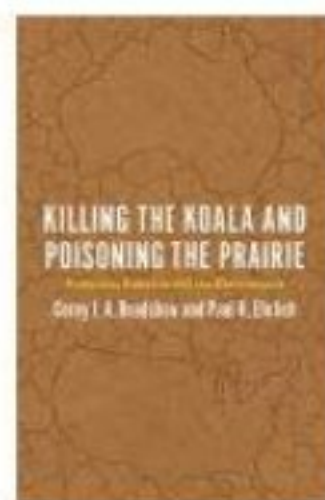
Tortured people will say absolutely anything to stop more torture

A lush, green future?

The troubled ecological history of two countries may help us understand today's attitudes

Killing the Koala and Poisoning the Prairie: Australia, America, and the environment by Corey J. A. Bradshaw and Paul R. Ehrlich, University of Chicago Press, \$22.50/£16

Adrian Barnett



IT SEEMS that we can't hear some things too many times, preferably delivered in a variety of formats. Environmental disasters, looming

or actual, pretty much top that list.

So it is with *Killing the Koala and Poisoning the Prairie* by two professional environmentalists: Corey Bradshaw, who directs the University of Adelaide's climate and ecology centre, and Paul Ehrlich of Stanford University, California, and the author of *The Population Bomb*.

Here they give a no-holds-barred analysis of their home nations to show how they got into their present predicament, and how we might avoid the current doomy trajectory. It is not a polite or gentle book, since the authors fear we are facing a "perfect storm of human-made environmental catastrophes".

Themes of sustainability, reduced meat consumption, over-population, capitalist greed and improving women's rights have become common currency since Ehrlich was making headlines in the 1970s, but this is no old-school tale of environmental woe. We get rapid-fire, how-it-is information from two scientists who are, they say, "too incensed to be politically correct". Greened-up hip-hop rather than whale-worried Baez.

The book starts modestly enough, by comparing 50,000



AMY TOENING/NATIONAL GEOGRAPHIC CREATIVE

and 10,000 years of pre-industrial occupation of the two vast, similar-sized, landmasses. While Australia's Aborigines developed a low-density, managed-burn culture that lasted 50 millennia on soils too poor for agriculture, North America's richer soils were subjected to a series of boom-and-bust agrarian cultures.

Both countries started out with harsh attacks on the environment. Within 2000 years of the Aborigines' arrival, most mammals weighing more than 50 kilograms were gone, including *Diprotodon* (a giant, browsing

"Education rarely includes dangerous topics like ecology at a level beyond the fluffy or the basic"

Desertification: part of a perfect storm of human-made disaster?

relative of the wombat); *Protemnodon* (a giant wallaby), and *Sthenurus* (a short-faced kangaroo). And in North America, Clovis culture was involved in similar megafauna mayhem.

From such grim beginnings, the authors plough on through their nations' apocalyptic eco-histories to the modern age, with Australia's 5000-kilometre dingo-proof fence, and the rich grass prairie of the US heartland, 99 per cent of which is now lost.

Bradshaw and Ehrlich dig deep to explore their cultural pasts as they struggle to explain the psychological roots of today's attitudes to the environment –

and how to treat it. This means a constant shift of focus, so readers need to pay strict attention. In one paragraph, they may quote the dangerous banalities of a particular politician, or the self-justification of a well-connected plutocrat; in the next, the fine points of how non-linearity in ecological impact assessments undermines current economic models.

Education, they say, is a big part of the problem. Designed to turn out good societal cogs, it rarely includes dangerous topics like ecology at any level beyond the fluffy or the basic. The result is a connection-free ecological ignorance among decision-makers, coupled with the belief that technology will save us, that population growth is a lesser environmental threat than climate change, and that humanity can continue under a growth-based economic system.

In pointing out the fallacies of the above, Bradshaw and Ehrlich are incisive, informed, ironic and sometimes rude to the point of libel. If the Earth is to have any humans and humans any Earth, they argue, the true challenge is to arrive at a population of 1 billion people, living in an equitable, non-growth economy. And this stasis must be reached humanely, so hopefully there will be a future where children ponder our plastic artefacts and know that their civilisation is better than ours.

Do read this book, but be prepared to be depressed, amused, enlightened and enraged by turns. ■

Adrian Barnett is a rainforest ecologist at Brazil's National Institute of Amazonian Research in Manaus

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**UNIVERSITY OF
WATERLOO**

IQC Institute for
Quantum
Computing

Faculty Position

Applications are invited for 1 or more tenure-track faculty positions, at the rank of Assistant Professor in the Institute for Quantum Computing (IQC) and any department in the Faculties of Mathematics and Science. The IQC is a collaborative research institute focused on realizing quantum technologies including sensors, actuators, quantum communication, and information processors. Membership in IQC is renewable, with an initial appointment of 5 years, and comes with research space, a teaching reduction of one course and a stipend. Only those candidates whose research program directly connects with the goals and ongoing research in IQC will be considered. Information about research at IQC can be found at <http://uwaterloo.ca/iqc/research>.

A PhD and significant evidence of excellence in research in quantum information science and technology and the potential for effective teaching are required. Responsibilities include the supervision of graduate students, as well as teaching at the undergraduate and graduate levels. Based on qualifications, salary range of \$75,000 to \$155,000 will be considered. Negotiations beyond this salary range will be considered for exceptionally qualified candidates. Effective date of appointment is negotiable. The search is open to all areas of quantum information. The search committee will consider all creative and energetic candidates in any area of research focused on advancing quantum information.

The University of Waterloo is host to the Institute for Quantum Computing. At present, IQC has a complement of 22 faculty members (growing to 33) from the Faculties of Engineering, Mathematics and Science. Interested individuals should upload their application via the faculty application form at: <http://uwaterloo.ca/iqc/positions>.

The application review process will begin on **December 1, 2015** and continue until **March 31, 2016**.

The University of Waterloo respects, appreciates and encourages diversity. We welcome applications from all qualified individuals including women, members of visible minorities, Aboriginal peoples and persons with disabilities. All qualified candidates are encouraged to apply; however, Canadian citizens and permanent residents will be given priority.

Three reasons to apply: <https://uwaterloo.ca/watport/why-waterloo>.

**KANSAS STATE
UNIVERSITY**



Assistant/Associate Professor Physics Education Research Kansas State University

The Department of Physics at Kansas State University seeks a faculty member to join its physics education research (PER) group. Experience with research on the teaching and learning of physics that complement and/or expands the existing PER efforts at KSU will be considered favorably. The successful candidate will be appointed at a rank of tenure-track Assistant or Associate Professor in the Physics Department. Candidates must present credentials which will justify appointment at one of these levels. Minimum requirements include a Ph.D. in physics education research or equivalent and research experience beyond the doctorate.

The Department has an outstanding physics education research program (KSUPER), which was founded in 1972. At present KSUPER includes two faculty members. A detailed description of research activities, post-docs and graduate students in KSUPER can be found at <http://www.phys.ksu.edu/ksuper>. For further information contact Eleanor Sayre (esayre@phys.ksu.edu) or Dean Zollman (dzollman@phys.ksu.edu).

The successful candidate will also demonstrate a strong commitment to teaching and mentoring of students and to serving a diverse population. He/she will be expected to obtain external funding for research activities, collaborate with other faculty in physics and other academic departments and build a national and international reputation in PER.

Applications should be sent, to PER Search Committee, 116 Cardwell Hall, Kansas State University, Manhattan, KS 66506-2601 or to persearch@phys.ksu.edu. Applications should include a cover letter that addresses qualifications for the position, a curriculum vita, and statements of research and teaching interests. The applicant should arrange to have three letters of reference sent to the address above.

Screening of applicants will begin on December 1, 2015, and continue until the position is filled.

Kansas State University is an Equal Opportunity Employer of individuals with disabilities and protected veterans and actively seeks diversity among its employees. Background checks required.

KANSAS STATE UNIVERSITY



ASSISTANT/ASSOCIATE PROFESSOR SOFT MATTER EXPERIMENT CONDENSED MATTER GROUP DEPARTMENT OF PHYSICS

The Department of Physics at Kansas State University seeks an experimental physicist with research interests in soft condensed matter physics. Areas of interest include nanoparticle assembly, biological problems at the cellular and molecular levels, emergent phenomena, macromolecules, structured fluids, colloids and aerosols, and light scattering and its application to these systems. Such a scientist might engage in experimental research at the molecular or continuum levels of these physical or biological systems. Cross disciplinary research plans that overlap with ongoing AMO projects in the department (strong field laser-matter interactions, plasmonics, ultrafast charge transport) will be reviewed with interest, but are not required. The successful candidate will be appointed at the rank of tenure-track Assistant or Associate Professor in the Physics Department. Candidates must have a PhD in physics or a closely related field. To be considered for the Associate level position candidates must present credentials which will justify appointment at that level. The successful candidate should also demonstrate a strong commitment to teaching and mentoring of students and to serving a diverse population.

The Department has outstanding experimental and theoretical Condensed Matter physics programs involving seven faculty members most of whom are involved in research related to soft matter physics. Faculty research interests include synthesis and self-assembly of nanoparticles, surface structure and surface interactions of nano/bio components, light scattering, metallic and conducting polymer nanowire fabrication and applications, cellular adhesion and migration, aggregation phenomena for both proteins and particles, and nanostructured magnetic systems. The soft matter group has strong ties and collaborations with faculty in Chemistry, Biology, Biochemistry, Mechanical Engineering, Chemical Engineering, Grain Science, and the Terry C. Johnson Center for Basic Cancer Research. A description of research in the physics department can be found at:

<http://www.phys.ksu.edu/research/condensed-matter.html>

Applications should be sent to **The Condensed Matter Search Committee, 116 Cardwell Hall, Kansas State University, Manhattan, KS 66506-2601** or to softmattersearch@phys.ksu.edu. In addition to a curriculum vita, applications should include statements of research and teaching interests. Candidates should arrange for three (3) letters of reference to be sent as well.

Kansas State University is an equal opportunity employer and actively seeks diversity among its employees. Background check required.



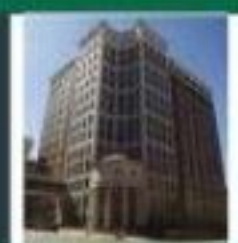
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UAB is also home to the NIH-funded IRACDA **Mentored Experiences in Research, Instruction, and Teaching (MERIT) Program**, which provides research and teaching experiences to qualified postdocs; for more info, please see www.uab.edu/meritprogram.

Visit our website at www.uab.edu/postdocs and select Postdoctoral Opportunities to view posted positions that interest you.



D. E. Shaw Research is a New York-based independent research laboratory that conducts basic scientific research in the field of computational biochemistry under the direct scientific leadership of Dr. David E. Shaw. Our lab has designed and developed multiple generations of a massively parallel supercomputer called Anton specifically for the execution of long-timescale molecular dynamics simulations. Our group is currently focusing on molecular simulations involving proteins and other biological macromolecules of potential interest from both a scientific and a pharmaceutical perspective. This is an ambitious, long-term project aimed at fundamentally transforming the process of drug discovery.

Members of the lab include computational chemists and biologists, computer scientists and applied mathematicians, and computer architects and engineers, all working collaboratively within a tightly coupled interdisciplinary research environment. For internships and full-time positions, we welcome applicants of all levels of experience from a broad range of backgrounds, including electrical and computer engineering, computer science, applied mathematics, chemistry, biology, physics, materials science, and related fields.

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To learn more about our research and current opportunities at the lab, we invite you to visit our website, www.DEShawResearch.com.

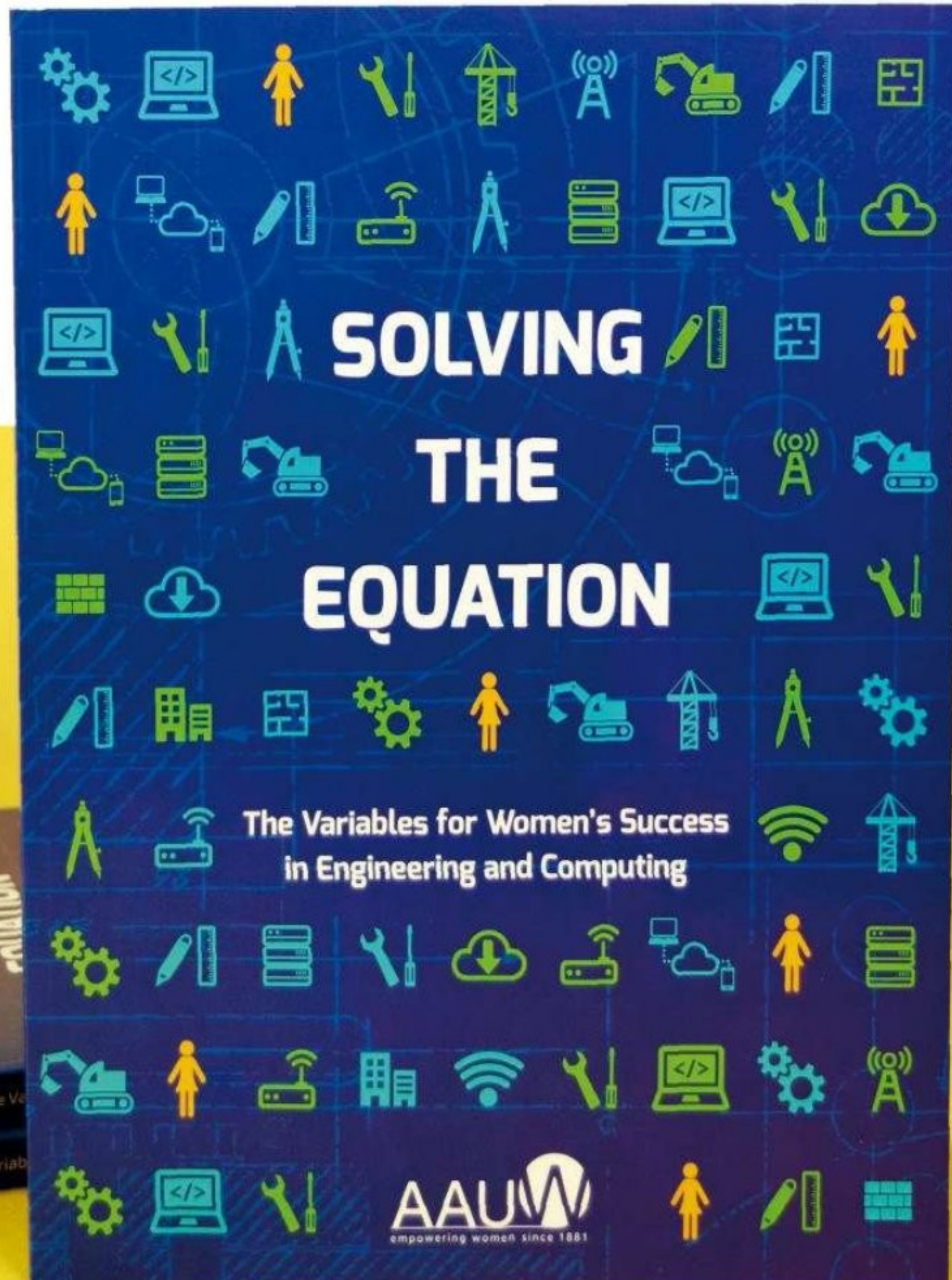
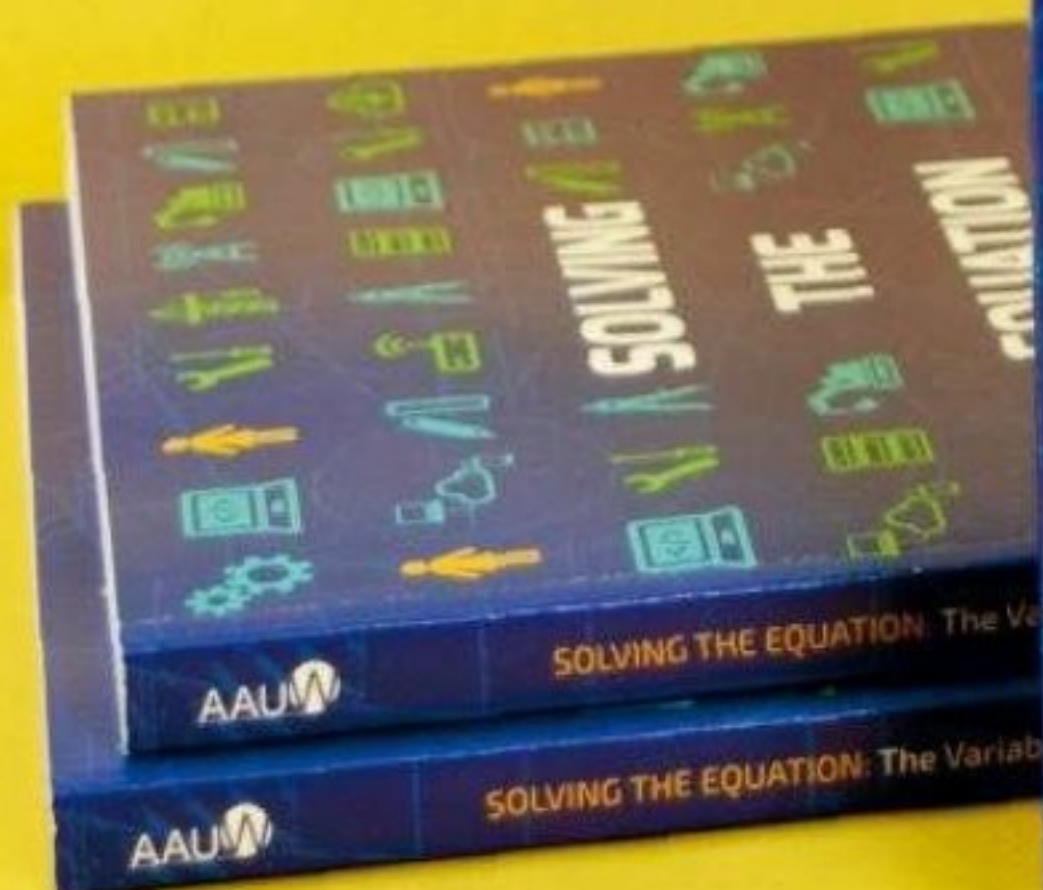
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We seek candidates who embrace and reflect diversity in the broadest sense. The University of Pennsylvania is an EOE. Minorities/Women/Individuals with disabilities/Protected Veterans are encouraged to apply.



UNIVERSITY OF
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IQC

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Research Assistant Professor

Applications are invited for a Research Assistant Professor position in the Institute for Quantum Computing (IQC) and any department in the Faculties of Mathematics, Engineering and Science. The IQC is a collaborative research institute focused on quantum information, science and technology. Membership in IQC is a five-year appointment, subject to re-evaluation after three years taking into consideration performance and availability of funding. Only those candidates whose research program directly connects with the goals and ongoing research at IQC will be considered. Information about research at IQC can be found at <http://uwaterloo.ca/iqc/research>.

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The application review process will begin on **Dec 1st** and continue until the position is filled.



Washington
University in St. Louis

Faculty Positions in Biochemistry and Molecular Biophysics

The Department of Biochemistry and Molecular Biophysics at Washington University School of Medicine invites applications for several tenured/tenure-track faculty positions at the level of Assistant/Associate/Full Professor. Successful candidates will have established a strong record of research. Applicants seeking tenured positions must have a strong record of external funding.

Outstanding individuals working in any area of biochemistry and molecular biophysics are encouraged to apply. The candidate's research should be aimed at addressing fundamental questions related to molecular mechanisms of biological or biomedical relevance. Current research in the department spans a wide range of topics including computational biology, membrane proteins, molecular motors, nucleic acid / protein interactions, protein structure, enzymology and signal transduction. Additional information about the department is available at <http://www.biochem.wustl.edu>. Washington University has a highly interactive research environment with vigorous interdisciplinary graduate and medical scientist training programs.

Applicants should email their curriculum vitae, brief description of their research interests, and contact information of three individuals to the Search Committee at bmbsearch@biochem.wustl.edu. The committee will request letters from these individuals as necessary.

Completed applications will be reviewed on a rolling basis, starting immediately. For full consideration, applications should be received by December 1, 2015.

EOE/Minorities/Vets/Disabilities. The School of Medicine at Washington University is committed to finding solutions to global health problems, including ones that affect minority and disadvantaged populations.



Monterey Bay Aquarium Research Institute

2016 POSTDOCTORAL FELLOWSHIP PROGRAM

Applications for the postdoctoral fellowship program at the Monterey Bay Aquarium Research Institute (MBARI) are currently being accepted. MBARI is dedicated to the development of state-of-the-art instrumentation, systems, and methods for scientific research in the oceans. Ongoing programs in marine robotics, ocean physics, chemistry, geology, and biology as well as information management and ocean instrumentation research and development exist at MBARI. Located in Moss Landing, California at the head of Monterey Canyon, MBARI enjoys convenient access to diverse oceanographic environments. The institute operates research vessels equipped with remotely operated vehicles, autonomous underwater vehicles, and diverse oceanographic equipment. In addition, MBARI operates the MARS seafloor cabled observatory. MBARI is a non-profit oceanographic research institute supported by the David and Lucile Packard Foundation.

Offers will be made to candidates from the fields of biological, chemical, and physical oceanography; marine geology; and ocean engineering. Candidates must be awarded the Ph.D. degree prior to commencing the two-year appointment and start during the 2016 calendar year. Applicants are encouraged to communicate with potential research sponsors at MBARI for guidance on project feasibility, relevance to ongoing research projects, and resource availability (http://www.mbari.org/about/postdoc_mentors.htm).

Application deadline: Wednesday, December 9, 2015

Selected candidates will be contacted in early March 2016.

Application requirements:

1. Curriculum vitae
2. At least three professional letters of recommendation
3. Succinct statement of the applicant's doctoral research
4. Potential research goals at MBARI
5. Supplemental information online form (http://www.mbari.org/oed/jobs/forms/postdoc_form_2016.htm)

Address your application materials to:

MBARI, Human Resources

Job code: Postdocs-2016

7700 Sandholdt Road, Moss Landing, CA 95039-9644

Submit by e-mail to jobs_postdocs@mbari.org (preferred), by mail, or by fax to (831) 775-1620.

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Woods Hole Oceanographic Institution

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Institutes - Each Institute fosters interdisciplinary research addressing critical issues, and we will award a scholarship to support related research: Ocean and Climate Change Institute; Coastal Ocean Institute; Ocean Exploration Institute; Ocean Life Institute

The National Ocean Sciences Accelerator Mass Spectrometer Facility (NOSAMS) will award a fellowship in the development and implementation of new techniques in marine science radiocarbon studies.

A joint USGS/WHOI award will be given to a postdoc whose research is in an area of common interest between USGS and WHOI Scientific Staff. The individual will interact with both USGS and WHOI based advisors on their research.

Awards are competitive, with primary emphasis placed on research promise. Scholarships are 18-months with an annual stipend of \$58,000, a research budget and eligibility for health and dental insurance. Recipients are encouraged to pursue their own research interest in association with resident staff. Communication with potential WHOI advisors prior to submitting an application is encouraged.

Further information may be obtained at:

www.whoi.edu/postdoctoral

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The 2016 Louisa Gross Horwitz Prize for Biology or Biochemistry

NOMINATIONS

All materials must be written in the English language and submitted electronically at:
<http://www.cumc.columbia.edu/research/horwitz-prize>

Deadline date: January 22, 2016

Renominations are by invitation only.
Self-nominations are not permitted.

The Louisa Gross Horwitz Prize was established under the will of the late S. Gross Horwitz through a bequest to Columbia University and is named to honor the donor's mother. Louisa Gross Horwitz was the daughter of Dr. Samuel David Gross (1805-1889), a prominent surgeon of Philadelphia and author of the outstanding *Systems of Surgery* who served as president of the American Medical Association.

Each year since its inception in 1967, the Louisa Gross Horwitz Prize has been awarded by Columbia University for outstanding basic research in the fields of biology or biochemistry. The purpose of this award is to honor a scientific investigator or group of investigators whose contributions to knowledge in either of these fields are deemed worthy of special recognition.

The Prize consists of an honorarium and a citation, which are awarded at a special presentation event. Unless otherwise recommended by the Prize Committee, the Prize is awarded annually. Dr. S. Lawrence Zipursky, at the University of California, Los Angeles, was the 2015 awardee.

QU QUALIFICATIONS FOR THE AWARD

The Prize Committee recognizes no geographical limitations. The Prize may be awarded to an individual or a group. When the Prize is awarded to a group, the honorarium will be divided among the recipients, but each member will receive a citation. Preference will be given to work done in the recent past.

N NOMINATIONS SHOULD INCLUDE

- 1) 1) A summary of the research on which this nomination is based (no more than 500 words).
- 2) 2) A summary of the significance of this research in the fields of biology or biochemistry (no more than 500 words).
- 3) 3) A brief biographical sketch of the nominee, including positions held and awards received by the nominee.
- 4) 4) A key publication list of up to ten of the nominee's most significant publications relating to the research noted under item 1.
- 5) 5) A copy of the nominee's curriculum vitae.

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IOWA STATE UNIVERSITY

Structural Biology Assistant Professor

The Roy J. Carver Department of Biochemistry, Biophysics and Molecular Biology at Iowa State University in Ames, IA has embarked on a transformational expansion of its structural biology research enterprise through a large philanthropic gift from the Roy J. Carver Charitable Trust. This major research initiative in Biomolecular Structure includes long-term investment in new instrumentation, endowed funds for graduate student training, and a series of new faculty hires working at the forefront of any aspect of structural biology.

As part of the faculty positions associated with this initiative, and as part of the interdisciplinary effort across the Iowa State University campus to expand structural biology research, the Department seeks a new tenure-track Assistant Professor to establish a vibrant, externally funded research program of international prominence and participate in graduate and undergraduate teaching.

Applicants should have a Ph.D. or equivalent degree, and research accomplishments indicative of the ability to establish an independent research program of national prominence.

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EDITOR'S PICK



The energy cost of a shared shower

From Tom Brydges

The corollary to the question headlining your leader article "What price the climate?" (17 October, p 5) is "What price on carbon?". The increases imposed on the price of crude oil by the Organization of the Petroleum Exporting Countries (OPEC) since 1973 show how global consumption can change. The price of crude oil went from \$3 per barrel to \$40 by 1981. Consumer prices for fuels increased about 25-fold. Global consumption swiftly declined.

Decreased consumption, driven by the price hike, was brought about by measures ranging from insulating houses to improved fuel efficiency. One popular idea was to shower with a friend.

Many countries have applied carbon pricing at rates of a few percentage points of the consumer cost and the result is very little, if any, reduction in fuel consumption. For governments, imposing carbon price rises akin to the OPEC experience is unthinkable.

However, reductions in fossil fuel use ultimately depend on using the fuel more efficiently or replacing it with green technology. This approach is the basis of the proposed Paris agreement and it is to be hoped that it is adopted and implemented aggressively by all countries.

Brampton, Ontario, Canada

Remedies for soil degradation

From Amir Kassam, Hugh Brammer, Brian Sims and Francis Shaxson, Tropical Agriculture Association

Joshua Howgego describes high-tech remedies for soil degradation (10 October, p 42). He doesn't mention, however, the practices of Conservation Agriculture, which are already used on around 155 million hectares worldwide (regrettably few of them in the UK).

Conservation Agriculture has three basic principles: to minimise soil disturbance by tillage; to maintain continuous soil cover by plant mulches and cover crops; and to rotate crops of different plant genera (preferably including deep-rooting, nitrogen-fixing legumes). More information can be found at fao.org/ag/ca/.

These measures increase and sustain the soil's organic matter, biota and fertility. They enhance the soil's capacity to absorb rainfall and store moisture, sequester carbon and reduce fuel use in tilling. They need to be promoted more extensively not only to enhance and sustain crop yields, but also to reduce the risks from floods, drought and water pollution. There is scope for more research to tailor Conservation Agriculture to soil, climatic, economic and socio-cultural environments and to measure the benefits, including carbon capture. London, UK

Shared language is no panacea

From Mike Daplyn

When will we discard the myth that shared language is a recipe for peace and cooperation (31 October, p 5)? Protestants and Catholics in Northern Ireland speak the same language. So do Serbs, Croats and Bosnians, and

likewise Rwanda's Tutsis and Hutus. The ancient Greeks all spoke mutually intelligible dialects, which didn't prevent the Athenians killing the men and enslaving the women and children of the island of Melos.

Sharing a language, as often as not, just helps you understand the vicious things the other lot say. Totescore, Isle of Skye, UK

There is more than one other way

From Al Cowie

I agree with reviewer Graham Lawton that Matt Ridley is wrong to have didactic beliefs, such as that the market would have come up with a better solution than the National Health Service (24 October, p 42). But Lawton's arguments are also one-sided.

In the rest of Europe, the market dictates health services while the state ensures everyone is covered by insurance. The result, in economies doing as well as the UK, is a better system than the NHS, cheaper, more caring (including time spent with doctors who are not overworked) and with choice. Please stop being so parochial.

London, UK

A universe with no special scale

From Miles Drake

There may be explanations for the observations of giant cosmic cold spots that Colin Stuart reports that are simpler than intruding multiverses (24 October, p 30). We can rewrite the cosmological principle based on the evidence presented.

First, let's assume the universe has structures of any size. The cosmological principle still applies, in that we are in a non-special place, because every point in the greater universe is special.

The uniqueness of our position is simply analogous to the "goldilocks zone for planet Earth", but it now applies to the particular region of the universe that we are able to inhabit.

In other words, we are in an expanding zone of the right density, that allowed us to emerge and observe our universe after a few billion years of evolution.

To me this feels much more grounded than intruding universes, or than Lawrence Krauss's conclusion in *A Universe from Nothing* (reviewed 14 January 2012, p 46) that we are in a special place at the only time we can observe the universe and deduce the standard model, since in billions of years we will be alone in our galaxy.

Federal Way, Washington, US

Do single-celled organisms do sex?

From Paul Rendell

Is it right to say that prokaryotic organisms don't have sex (19 September, p 28)? They can exchange genetic material via virus-like particles.

Why not call this "sex"? Barmouth, Gwynedd, UK

From Karen Scott

Single-celled organisms don't need sex. They exchange DNA segments. They can even select particularly useful bits to exchange. Only multicellular organisms are stuck with original DNA when cloning; that, or waiting for some virus or fungus to screw with their DNA. Ithaca, New York, US

The editor writes:

■ Some scientists do describe prokaryotes as having sex. This is different, however, from sex involving the fusion of two gametes, each with half as many chromosomes as the adult. This allows genetic recombination across the entire genome.

f “With the amount of our data the government has lost or left on trains, this is insane”

Nigel Vickers comments on the UK government's plans to access browsing history and other “metadata” (newscientist.com/article/dn28447)

Bored, bored and maybe depressed

From Peter Standen

Your article on boredom mentions a well-known saying that I recall, slightly differently to the author, as “there’s no such thing as bored, only boring people” (29 August, p 36). This may be a parent’s exhortation to a child meaning “the answer is up to you, no point complaining”. But all the author’s explanations for feeling bored – an evolutionary “kick up the backside”, dopamine depletion, personality trait, overstimulation, failure of the attention system – suggest it is far from being a personal choice.

When I have been bored, I have often also felt depressed and unable to see the enormous variety of interesting things and creative opportunities around me. I was struck by how many of the symptoms of boredom were also consistent with depression.

Psychological variables such as autonomy versus dependence or internal versus external “locus of control” may be more predictive

of both conditions. Being slightly bored or depressed are useful signals of the need to change our behaviour, as Caroline Williams notes, but as I see it we only get stuck in them when we don’t listen to the signal.

Darlington, Western Australia

A new solution to save free will

From Charles Merfield

Nathaniel Hellerstein and Anthony Castaldo (Letters, 10 October) both point to an alternative “solution” to the free will issue. Yet the laws of physics are a red herring.

While the common conception is that all of biology is chemistry and all of chemistry is physics, this is incorrect, because “below” physics and “above” mathematics sits the science of information. Consciousness and free will aren’t based on physics: they are information phenomena. None of these things emerge from chemistry and physics: they emerge from the even more

fundamental information “layer”.

So as Hellerstein suggests, free will and consciousness could be the results of self-causation, the “strange loops” that cognitive scientist Douglas Hofstadter describes, which emerge directly from information. To reconcile free will with our scientific knowledge, we just need to ignore physics and go with information.

Lincoln, New Zealand

Key-ring orbits not corkscrew planets

From Greg Egan

You report the idea of a planet corkscrewing back and forth between two stars, from a paper by Eugene Oks (19 September, p 38). This is thrilling, all the more so for a science fiction author like me. Unfortunately, I read the paper differently.

As soon as Oks allows for the fact that the two stars are not motionless, planetary orbits around the axis between them can only be stable when their plane crosses that axis very close

to one or other star – at not much more than 1 per cent of the distance between them. That would make the orbit more of a key ring than a corkscrew.

Worse, it seems to me that the conservation of angular momentum means the planet’s orbital plane must stay aligned in a constant direction – it may start out orbiting the axis, but once the stars turn in their own orbit by any significant amount this would no longer be the case.

Perth, Western Australia

Canada’s flag is a maple leaf

From Duncan MacKenzie

I was startled to read that Fred Pearce suspects “sugar maples, yellow birch, red spruce and others are likely to shift north into Canada” (3 October, p 42). Too late! They are already here.

Guelph, Ontario, Canada

For the record

■ Joseph Bramante, who suggested that dark matter could supply mass for supernova explosions, is at Notre Dame University in Indiana (31 October, p 14).

■ There’s more to life than that: we meant to say that graphite flecks in 4.1-billion-year-old zircon crystals had a ratio of carbon-12 to carbon-13 isotopes that is characteristic of organic origins (24 October, p 12).

■ Vincent van Gogh said in letters that he used chrome yellow pigment in all seven of his *Sunflowers* series of paintings (31 October, p 17).

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Five-year awards provide \$500,000 to bridge advanced postdoctoral training and the early years of faculty service. These awards are intended to foster the early career development of researchers with backgrounds in the physical/mathematical/computational/engineering sciences whose work addresses biological questions. BWF has moved to a self-nomination format for this award.

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Institutional Program Unifying Population and Laboratory Based Sciences:

Five-year awards provide \$2.5 million to unite population-level and laboratory-based biological sciences. The award supports the training of researchers working between existing research concentrations in population approaches to health and in basic biological sciences. The goal is to establish interdisciplinary training programs by partnering researchers working in disparate environments and intellectual frameworks.

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Preterm Birth Initiative: Provides \$600,000 over a four-year period to bring together a diverse interdisciplinary group with the more traditional areas of parturition research to address the scientific issues related to preterm birth.



SCIENCE EDUCATION

Career Awards for Science and Mathematics

Teachers: Five-year awards provide \$175,000 to eligible science or mathematics teachers in the North Carolina public primary and secondary schools. The purpose of this award is to recognize teachers who have demonstrated solid knowledge of science or mathematics content and have outstanding performance records in educating children. The award is a partnership between the North Carolina State Board of Education and BWF.

Student Science Enrichment Program:

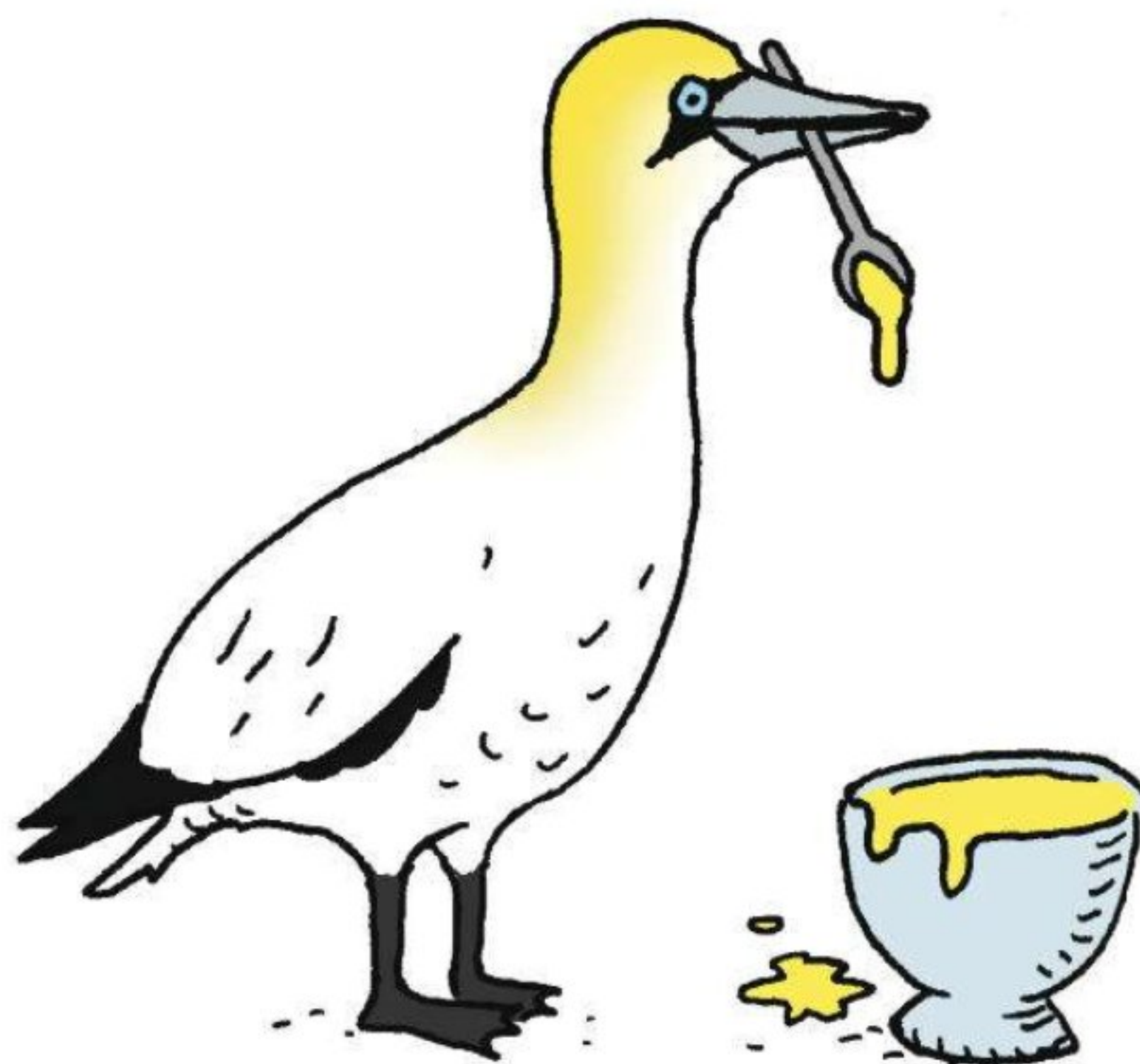
Three-year awards provide up to \$180,000 to North Carolina nonprofit organizations, including public/private schools, universities, colleges, and museums. This program supports creative inquiry-based science enrichment activities that occur outside the typical school day for K-12 students. The program's goals are to nurture students' enthusiasm about science, expose them to the excitement of scientific discovery, and interest them in pursuing careers in research or a variety of other careers in science.

Promoting Innovation in Science and

Mathematics: Awards provide teachers with funding for materials, equipment, and training to conduct hands-on, inquiry-based science and mathematics projects in North Carolina public schools.

The Burroughs Wellcome Fund is a private foundation located in Research Triangle Park, North Carolina. Find out more at bwfund.org

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FACED with an ever-growing list of substances its citizens are ingesting to get high, the UK government has decided it would be easier to ban every psychoactive substance by default, and instead create a list of mind-altering chemicals that British subjects are permitted to consume, such as tea (20 June).

Despite the government's own Advisory Council on the Misuse of Drugs (ACMD) writing to the Home Secretary to warn that this is "unenforceable" (18 July), the bill has now progressed to the stage where MPs can scrutinise the text and make amendments. MP David Amess has been selected to co-chair the committee in charge of this process.

Many will of course recall that Amess has a history on drug reform, as he was fooled into condemning the fictitious drug "cake" on the satirical TV show *Brass Eye*.

Feedback thinks it's a shame Amess is unlikely to repeat his colourful description of legal highs

as "yellow death bullets" and their consumers as "custard gannets". But who better to chair a nonsensical bill than the man who campaigned against a non-existent drug?

SPEAKING of non-existent drugs, Home Secretary Theresa May unveiled the latest addition to what promises to be a very long list of exemptions to the Psychoactive Substances bill: homeopathic medicine.

Perhaps because it is neither a substance, not any more psychoactive than a sugar tablet, the quack remedy was singled out in a reply to the ACMD by way of refuting the suggestion that the bill's definition of psychoactive substances was too broad.

The water cure will continue to be regulated under laws governing medicines, meaning the UK is heading toward the peculiar state where ineffective therapies are enshrined in

medicines legislation, while tea is an exempted substance under drugs legislation.

BROWSING Hansard, Feedback discovers from the second reading of the bill that £180,556 has been spent on education programmes about new psychoactive substances. We can't help but wonder if any of it was spent in Westminster.

MORE drugs trials: writing at Politics.co.uk, Dee Sullivan reports on the quantum state of cannabis. GW Pharmaceuticals was allowed to grow the plant under licence to create Sativex, a tincture to treat the symptoms of multiple sclerosis.

However, cannabis is regulated as a Schedule 1 drug in the UK, a category that defines it as having no therapeutic value. Rather than cut through this Gordian knot, a new loop was added: cannabis is a Schedule 1 substance, except when it is mixed with alcohol and peppermint flavouring to make Sativex. Only then does the active ingredient have therapeutic value, moving it to Schedule 4.

MORE quantum states: Feedback recalls that previously, the Misuse of Drugs Act 1971 made cannabis oil a Class A substance, carrying penalties for possession on par with those for heroin and cocaine.

However, so long as the cannabis oil remained in the leaf, it was a more benignly viewed Class C substance. A 2008 revision subsequently moved all forms of cannabis to Class B. A compromise, of sorts?

OUR own ban, on nominative determinism, proves no less fallible. Sam Molloy writes: "I know we aren't supposed to mention the N and D words, but we may have justification for an exemption here." He directs our attention to the line "Mike Penning, minister of state for policing and justice, has written..." (10 October).

Sam wonders: "Is this first time that not one but two alternative

career activities have been nominatively determined in the one sentence?"

REPORTING from the front lines in the battle for equality: Warren Bebbington, Vice Chancellor for the University of Adelaide, writes to his colleagues to announce he is chairing Male Champions of Change, an effort to "address the gender imbalance in senior roles across the University".

Bebbington informs us that the panel is "comprised of a group of senior male staff, created to see how we might address the issue of improving women's representation in leadership". Good luck boys!

FINALLY, *Newsweek* announces somewhat superfluously that "Dolphin-assisted childbirth is a bad idea". Expectant couples, we are told, are travelling to spiritual retreats in Hawaii and



the Black Sea so that "unpaid and untrained" cetacean midwives can help deliver their offspring.

Newsweek notes that there are countless other ocean dwellers, from bacteria to sharks, that may wish to bond with mother and child in less than idyllic ways. Nonetheless, Feedback thinks that if they prove their mettle, we may have found the answer to the UK's shortage of nursing staff.

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"We will ensure that we insert what we want to insert... while at the same time having a blanket ban." Mike Penning squares the circle of the Psychoactive Substances bill

Slick thinking

Why are dispersants used to treat oil spills? Wouldn't a coagulant simplify containment and clean up?

■ Coagulants are sometimes used to treat turbidity, or cloudiness, in water. This causes the particles responsible to coalesce, or flocculate, making them easier to remove by precipitation or filtration. When oil is in water, the two form a colloid – a solution in which one substance of microscopically dispersed insoluble particles is suspended throughout another. Colloidal particles do not usually flocculate on their own because they often carry an electric charge, thus repelling each other. Coagulants carry an opposite charge to neutralise the colloid, allowing flocculation.

However, the hydrocarbon molecules that constitute oil spills are non-polar, carrying no electric charge, so do not mix with electrically polarised water molecules or coagulants. Dispersants, such as detergent, have a split personality. Their molecules have a long, non-polar tail and a short, electrically charged head. The tails dissolve in oil to form microscopic droplets called micelles, from which heads stick out into the water, allowing mixing and thus easier dispersal. The micelles then disperse to hopefully be biodegraded.

However, oil micelles can cause damage. You need look no further

than the economic and environmental problems caused by the Deepwater Horizon disaster of 2010 in the Gulf of Mexico. About 7 million litres of dispersant were used to combat this spill.

Sadly, a dispersant can be more toxic than the oil it dissipates – and worse, can act in synergy with the oil, causing toxicity many times greater than the sum of the individual toxicities of the oil and dispersant.

*David Muir
Science Department
Portobello High School
Edinburgh, UK*

Wave goodbye

Sound waves fade over distance. However, we can see light waves arriving from billions of light years away. Why don't incoming light waves dissipate before they reach us?

■ The answer stems from the fact that light energy is not dissipated as it travels through the vacuum of space, whereas sound cannot travel through a vacuum and needs a material in order to propagate.

When sound or light waves pass through material, the matter takes a toll. Even in transparent material, light is absorbed and the amount lost often depends on the light's wavelength. In the ocean, for example, a large fraction of the red end of the visible spectrum dissipates within about 10 metres of the surface – and not much

light of any wavelength reaches depths greater than 50 metres, even in very clear water.

By contrast, sound usually suffers less attenuation through water than light does. Certainly, a submerged scuba diver will hear the sound of an engine and rotating propeller even if the boat responsible cannot be seen.

Unless it is absorbed by an object blocking the way, sound or light from a point source spreads out in all directions, and its energy expands over the surface of an imaginary sphere, which gets bigger with time.

So part of the reason why sound (or light) seems to fade with distance from the source is because its energy is being spread over a greater surface area. Of course, if stars and galaxies did not radiate such prodigious amounts of light energy, they would not be visible from billions of light years away.

*Mike Follows
Sutton Coldfield, West Midlands, UK*

This week's questions

DIVIDE AND RULE

I saw this tree in Austria over the summer (see photos). The trunk seemed to divide near the base and became almost three separate trees as it climbed higher. What species is this, and is it a normal occurrence? If so, what purpose does the division serve?

*Alan Friel
Cork, Ireland*



LONG IN THE TOOTH

My dentist says that dental enamel is never replenished and we have to make do with the adult set of teeth throughout our grown-up lives. I can't believe that after some 80 years of chomping and grinding, my teeth are still the same shape, without apparent signs of wear. Is he right? If so, why am I generally still toothily intact?

*John Everest
Pinner, Middlesex, UK*

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